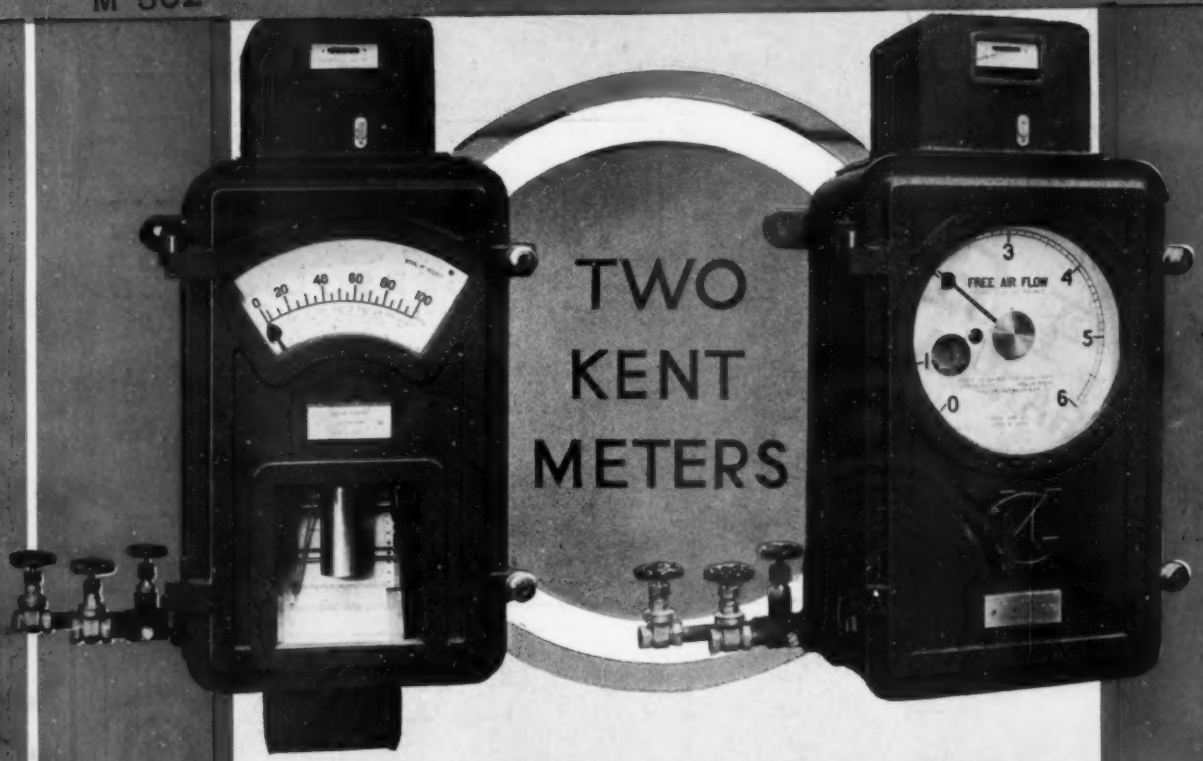
Vol. 17 No. 102 APRIL, 1938. Price 2/- [Subscription 24/- per annum post free.]

METALLURGIA

THE BRITISH JOURNAL OF METALS

669.05
M 562



Ring-balance recorders are designed expressly for the measurement of the flow of low pressure gas or air. Note the open equal spacing on the dial, due to the use of the machine-generated cam to modify the natural square-root law of the differential pressure. This sturdy instrument can be operated either with an orifice fitting or a Pitot tube, it is unaffected by dust, heat or vibration, and cannot be damaged by overload, while the record can be transmitted electrically if required. The instrument on the right is based on the same principles and possesses the same general features, but it indicates and integrates only, without charting a record.

The Multelec, shown below, is sensitive, yet of extemely rugged design. It controls pH value in any solutions and controls the conditioning of boiler feed water. It also controls any temperatures ranging from minus 300 deg. Fahr. to plus 3,000 deg. Fahr., a change being detected on the recorder within two seconds of its occurrence.

GEORGE KENT LTD., LUTON, BEDFORDSHIRE. LONDON OFFICE: 200 HIGH HOLBORN, W.C.1. JOHANNESBURG: P.O. Box 7396. PENANG: P.O. Box 321. Agents:—Sydney: Gibson, Battle & Co., Pty., Ltd., P.O. Box 1595 BB. Melbourne: Davies Shephard Pty., Ltd., Clarke Street. Brisbane: Underhill, Day & Co., Pty., Ltd. Wellington, N.Z.: Cory-Wright & Salmon, P.O. Box 1230. Bombay: W. H. Brady & Co., Ltd. Royal Insurance Buildings, Churchgate Street.

GEORGE KENT

MADE BY

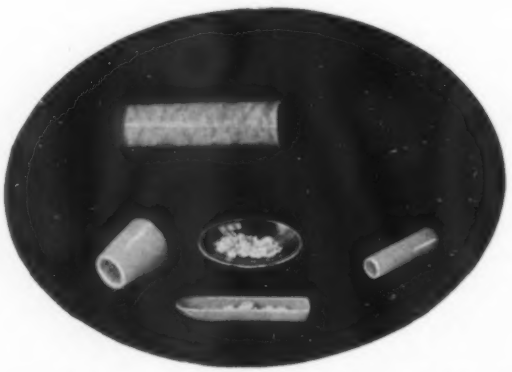
McKECHNIE BROTHERS LIMITED

BRASS RODS, STAMPINGS, and NON-FERROUS INGOT METAL MANUFACTURERS

ROTTON PARK STREET, BIRMINGHAM 16 Phone: Edgbaston 0380 (seven lines). Telegrams: "McKechnie, Birmingham." **LEEDS: Prudential Buildings, Park Row. NEWCASTLE-on-TYNE: 90, Pilgrim St. LONDON: 17, Victoria St., Westminster, S.W.1. MANCHESTER: 509-13, Corn Exchange Buildings 4. Sulphate of Copper and Lithopone Works: WIDNES, Lancashire.**

VITREOSIL

PURE FUSED SILICA



HEAT & ACID PROOF

LABORATORY WARE

No other Laboratory Ware combines heat and acid resistance to the same degree as VITREOSIL. It is invaluable for ignition work.

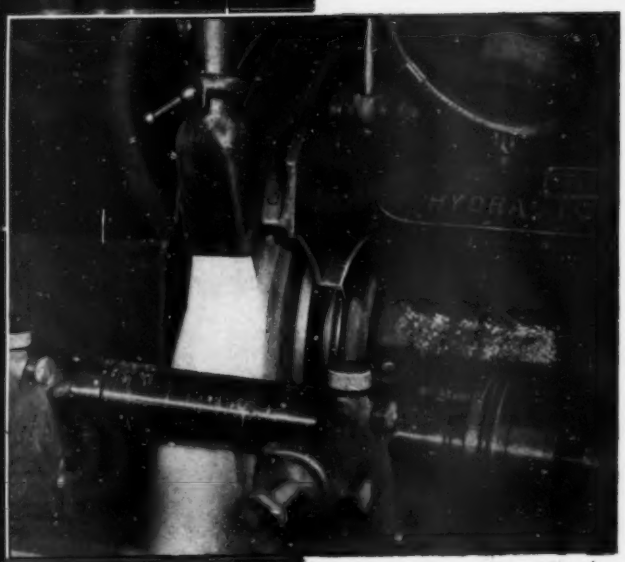
The THERMAL SYNDICATE Ltd.

Established over 30 years

Head Office & Works - **WALLSEND, NORTHUMBERLAND**

London Depot - **Thermal House, 12-14, Old Pye Street, Westminster, S.W.1.**

GRINDING NITRALLOY



The difficulties that arose in the grinding of Nitralloy when it was first introduced to be used for parts subject to wear have now been satisfactorily overcome by the use of White Aloxite Brand Grinding Wheels.

Nitralloy parts ground on these Wheels give much longer life because the White Aloxite Brand Grinding Wheel imparts a burnish finish.

Write for details on the grinding of Nitralloy, both in soft and hardened state.

The illustrations show a White Aloxite Brand Grinding Wheel in operation on the grinding of Nitralloy, grinding wheel spindles on a Churchill Hydrauto Plain Cylindrical Grinding Machine.

WHITE ALOXITE
GRINDING WHEELS

SILVER SOLDER

FOR ALL PURPOSES

SEND FOR SAMPLES

PURCHASERS OF
GOLD, SILVER AND OTHER PRECIOUS METALS CONTAINED IN RESIDUES AND WASTE MATERIAL

CHARLES HARROLD & CO. LTD.

Bullion Dealers, Assayers & Refiners,
Telephone : Central 3102 (3 lines).
2 & 3, St. Paul's Square, BIRMINGHAM
Telegrams : "AURUM, BIRMINGHAM."

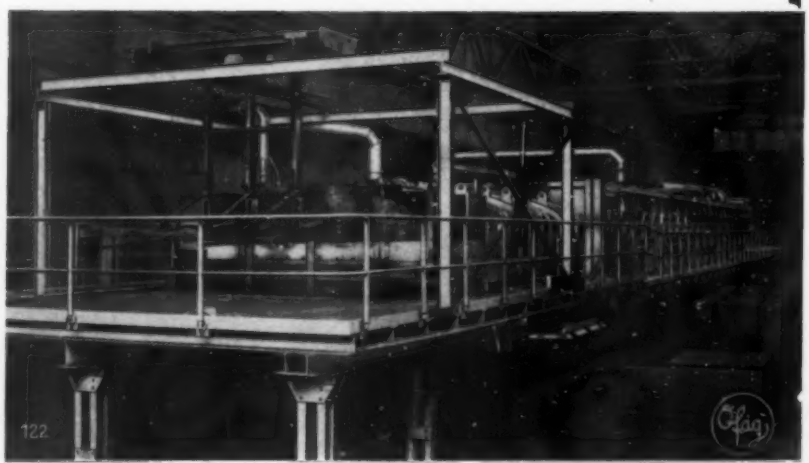
Ofag

OFAG OFENBAU A.G.

Dusseldorf, Kaiserswertherstrasse 105

MODERN INDUSTRIAL FURNACES

Special designs of
FULL AUTOMATIC
and
CONTINUOUS FURNACES
for all
HEAT-TREATMENTS

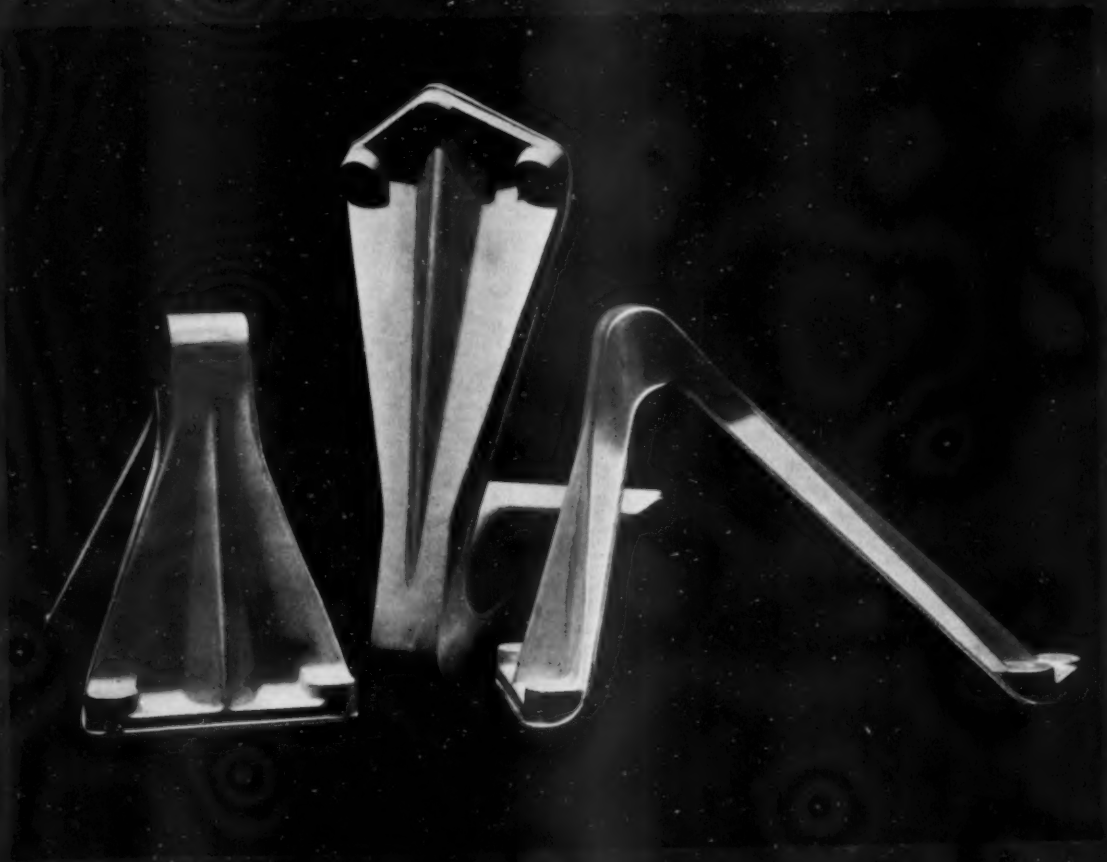


Sheet-normalizing Furnace with continuous walking beams in one level.

Sole Agents in England :
ROBSON REFRACTORIES LTD., 47, Coniscliffe Road, DARLINGTON

STAMPINGS IN

ALUMINUM



STAMPINGS IN

ALUMINUM

The illustration overleaf shows

TYPICAL STAMPINGS

IN HIDUMINIUM R.R.56

HIGH DUTY ALLOYS LTD.

SLOUGH

T.G.S.

How MICROMAX POTENTIOMETERS CELEBRATE HER 25TH. ANNIVERSARY

This was good

●and in its day was recognised as the worlds standard —often imitated but never equalled.

But this is better

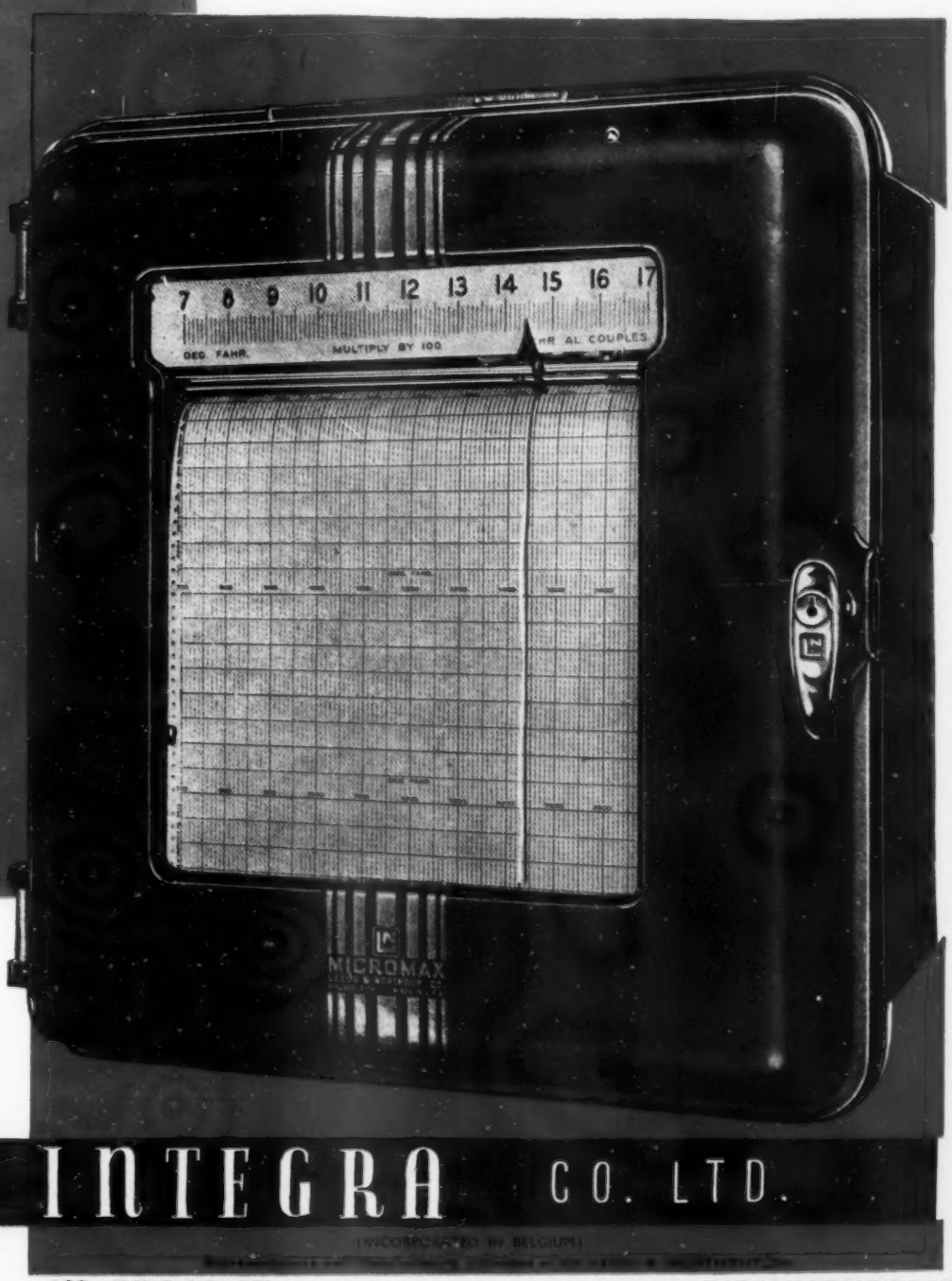
● Here is the new "MICROMAX" Silver Anniversary Model, the latest Leeds & Northrup recording controlling potentiometer pyrometer. The product of over 25 years' specialised experience, it adds important advantages to a recorder already unmatched in industrial pyrometry.

● Single point or multi-point (up to 16) with records in one or several colours. Automatic controllers for any applications.

● "MICROMAX" pyrometers are extensively used in large British factories as well as abroad. Their accuracy is unaffected by wear on the balancing mechanism and is checked automatically and constantly throughout the day.

● Consult us on all your heat-treatment problems. In the "S & N range", "Hump" Vapocarb hardening and "Homo" tempering furnaces, there is equipment that will give uniformly good results for minimum cost.

Write for Booklet N.33A



THE INTEGRA CO. LTD.

(INCORPORATED IN BELGIUM)

183, BROAD ST., WORKS : 75-79, ISLINGTON ROW, **BIRMINGHAM 15**

Impressions during the casting of a piston, weighing approximately 6 cwts, in "Y" ALLOY

"Y" ALLOY (B.S.S.L-35)
OR
LOW EXPANSION ALLOY (B.A./ 42)

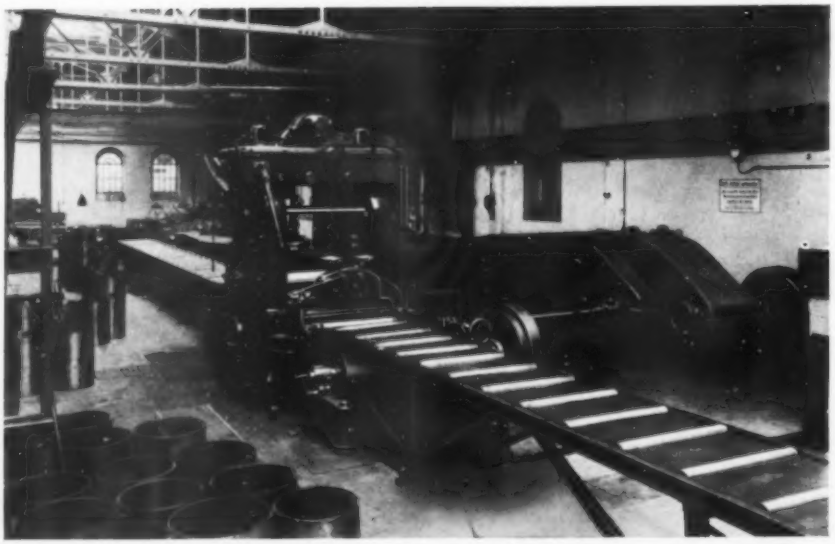
WILLIAM MILLS LTD.

GROVE ST · BIRMINGHAM

SCHMITZ

Walzmaschinenfabrik August Schmitz, Düsseldorf, Germany

TWO- AND FOUR-HIGH, CLUSTER AND HIGH-SPEED ROLLING MILLS with forged and hardened steel rolls, for cold-rolling iron, steel, brass, copper, aluminium, etc.



Two-high Reversible Strip Cold Rolling Mill 32" wide.

AUXILIARY MACHINES OF ALL DESCRIPTIONS, slitting, straightening and pickling machines, etc.

COMPLETE PLANTS FOR ROLLING ALUMINIUM, TIN AND LEAD FOIL in long length.

FORGED AND HARDENED STEEL ROLLS of all dimensions.

STEELS FOR MACHINE TOOLS

N° 4
NICKEL ALLOY CASE-HARDENING STEELS

Resistance to wear and abrasion has long been secured by case-hardening ordinary mild steels or even wrought iron. But the nickel alloy steels compare so favourably with the cheaper materials that they can frequently be used without appreciable addition to the cost. For instance, it is usually possible to avoid a double quench, thus saving expensive heat-treatment and straightening operations, and reducing the number of wasters. They also have a fine machining finish and the graduation from case to core is more uniform. Perhaps most important of all are the mechanical properties of the core, typical examples of which are given in the table below.

CHEMICAL COMPOSITION				Point Yield	Max. Stress	Elongation per cent.	Reduct. of area per cent.	Izod ft. lb.
C.	Mn.	Ni.	Cr.	Tons per sq. in.				
3% Nickel Case-Hardening Steel. Hardened.								
0·14	0·50	3·30	0·10	38·0	51·3	21·5	51·0	60
5% Nickel Case-Hardening Steel. Hardened.								
0·14	0·35	5·25	0·10	54·5	68·6	18·5	51·0	45
3½% Nickel Chromium Case-Hardening Steel. Refined and Hardened.								
0·12	0·40	3·25	1·0	48·2	60·5	19·0	50·5	50
4½% Nickel Chr. Steel. Hardened.								
0·18	0·50	4·25	1·3	74·2	87·8	12·5	40·5	32

The above information is selected from our publication A.11 which gives details of the mechanical properties and heat-treatments of a wide range of nickel alloy steels.

Machine tool builders will be interested also in our data sheet AA.5 "Recommended Materials for Machine and Hand Tools." Return the coupon.

I am interested in steels for machine tools. Please send me copies of your publications A.11 and AA.5

Name.....

Address.....

.....

To The Bureau of Information on Nickel,
THE MOND NICKEL COMPANY, LIMITED
Thames House, Millbank, S.W.1

38A.23

THE BUREAU OF INFORMATION ON NICKEL

THE MOND NICKEL COMPANY LTD · THAMES HOUSE · MILLBANK · LONDON SW1

The A B M T M group of machine tool makers covers the whole field of machine-tool building, giving the engineer at home and abroad a unique manufacturing and sales service.

Apart from the main specialities of the Associated firms, customers have the advantages of the pooled research, the accumulated experience and the entire technical resources of the whole group.

The abundant advantages thus provided by group co-operation will be obvious. The after-sales service is of a kind beyond the scope of the single manufacturer.

For further particulars write to:

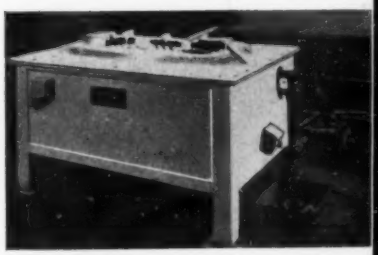
17, GROSVENOR GARDENS

LONDON——————S.W.1

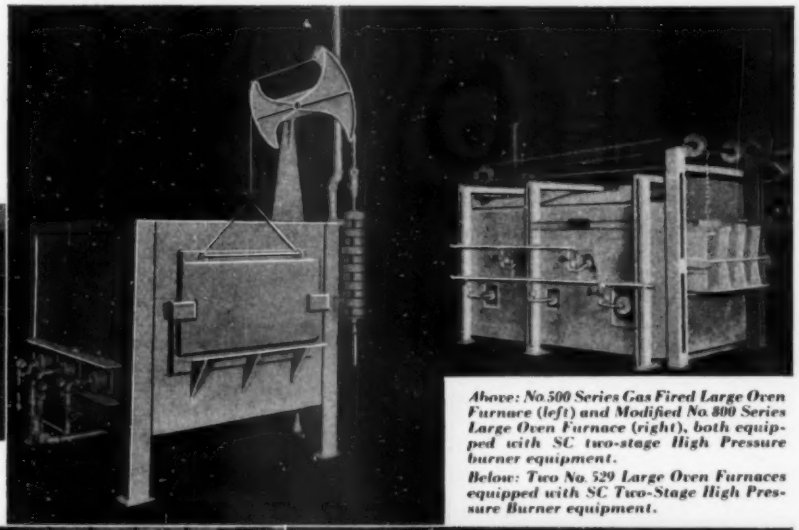
ASSOCIATED BRITISH MACHINE TOOL MAKERS LIMITED TRADE MARK

WE HAVE A CORRECT TYPE AND SIZE OF FURNACE FOR ANY HEAT-TREATING OPERATION

Whether the operation is heating, forging, hardening, annealing, normalizing, drawing, drying, melting, there is a correct size and type of Furnace to do the job.



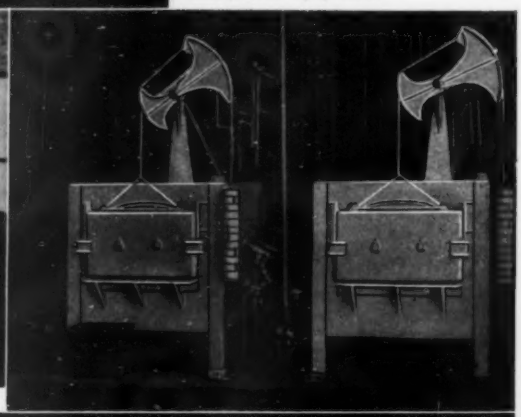
Pot type furnace used for heat treating miscellaneous small parts. SC Low Pressure firing equipment and Automatic Temperature Control.

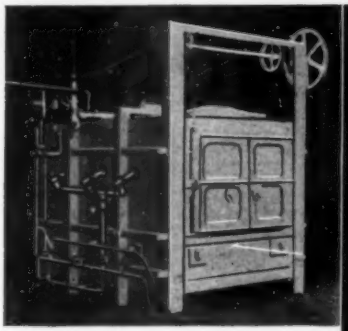


Above: No. 500 Series Gas Fired Large Oven Furnace (left) and Modified No. 800 Series Large Oven Furnace (right), both equipped with SC two-stage High Pressure burner equipment.

Below: Two No. 529 Large Oven Furnaces equipped with SC Two-Stage High Pressure Burner equipment.

High Temperature Oven Furnace (left) and Pot Hardening Furnace (right). Both of these units are equipped with SC Automatic Proportioning burner equipment for Low Pressure gas. Also, with Automatic Temperature Controls.





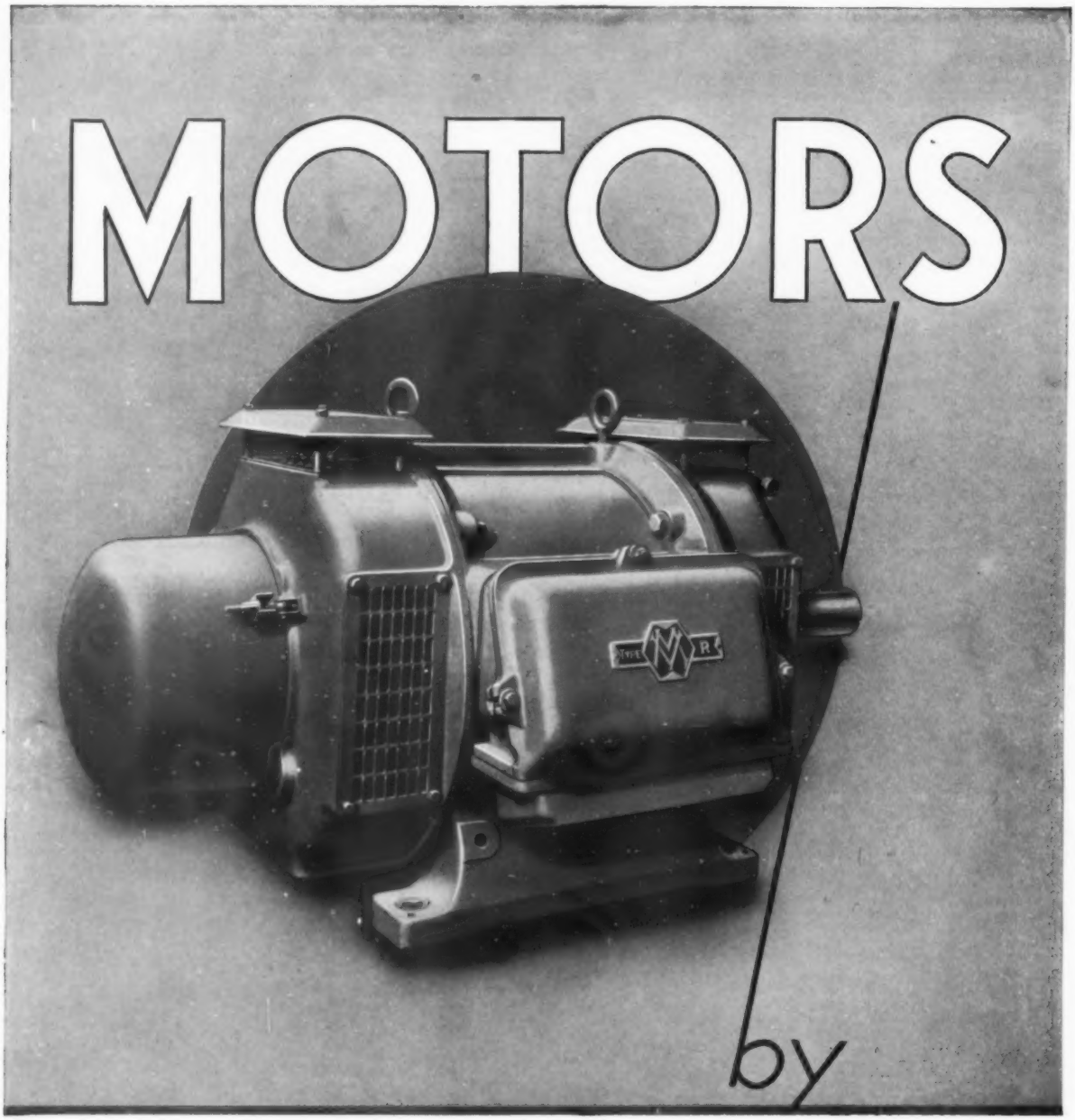
Large Oven Furnace for heat treating in a large foundry.

Battery of Standard RATED Small Oven Furnaces used for tool hardening. These furnaces are equipped with SC Automatic Proportioning burner equipment.

BRITISH FURNACES LTD.

Industrial Furnace Engineers

CHESTERFIELD



A·C or D·C for STEEL WORKS · CRANES · BOILER HOUSES · TRACTION
MACHINE TOOLS · COLLIERIES . MARINE · ETC.

METROPOLITAN Vickers
ELECTRICAL CO., LTD.
TRAFFORD PARK · MANCHESTER 17

J.A/40

SEMI-AUTOMATIC TUBE DRAWING PLANT

for drawing tubes with advancing mandrel bar. Mechanical Intruding of Mandrels. Automatic Tube Discharge Device. Automatic Dog Return Device. Roller Conveyors, Realing Machine. Automatic Mandrel Extracting Bench. Mandrel Transport and Lifting Device.

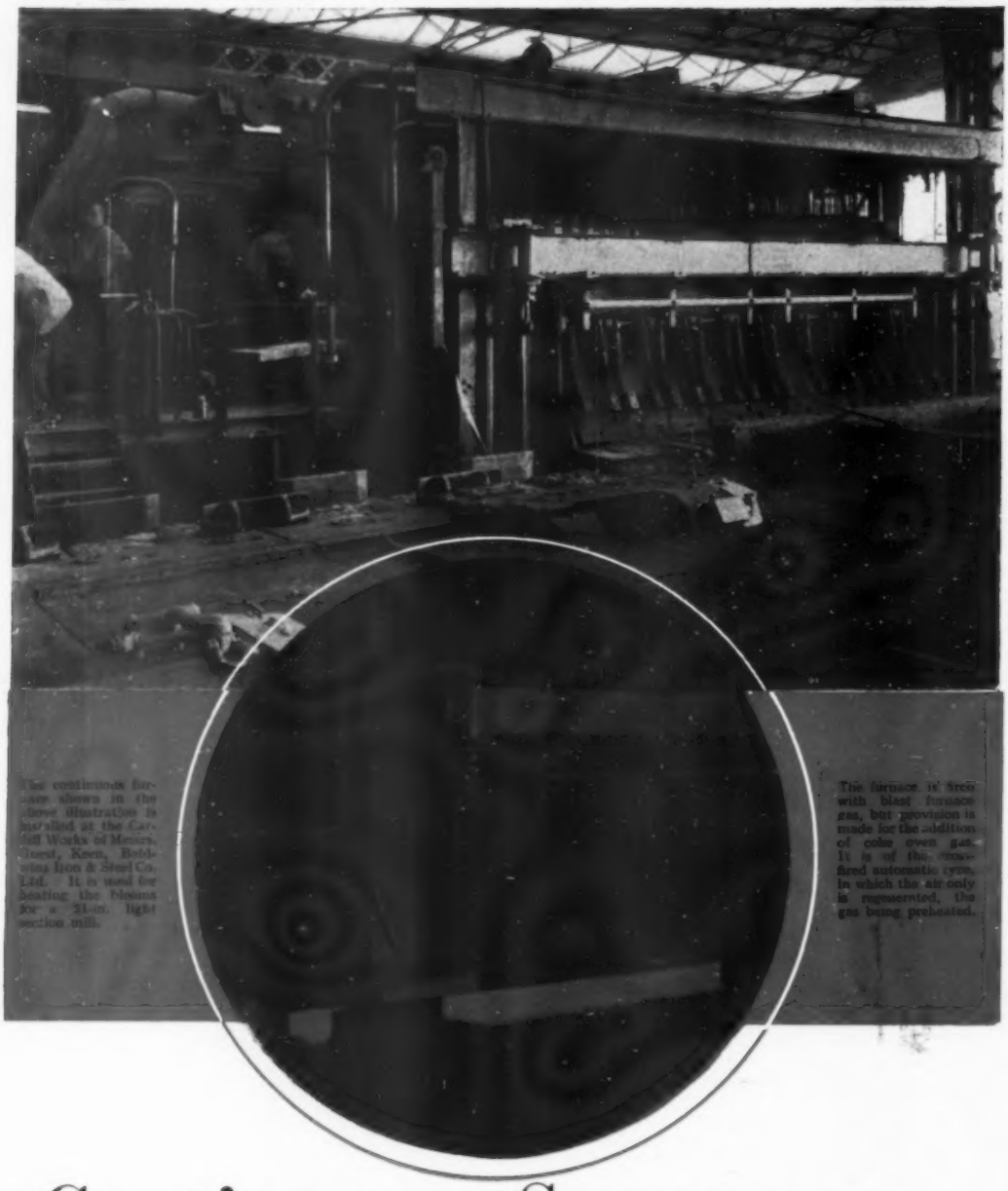
Only two Operators required for a Production of 17 Tubes per Hour.

All movements electrically push button controlled. Full particulars on request.

SUNDWIGER EISENHÜTTE
Maschinenfabrik Grah & Co.
Sundwig, Krs. Iserlohn,
Germany

British Sole Agents :
MACHINE SHOP EQUIPMENT LTD., 124, VICTORIA STREET, WESTMINSTER, LONDON, S.W.1

PRIEST FURNACES LTD



The continuous furnace shown in the above illustration is installed at the Cardiff Works of Messrs. Guest, Keen, Baldwins Iron & Steel Co. Ltd. It is used for heating the blooms for a 21-in. light section mill.

The furnace is fired with blast furnace gas, but provision is made for the addition of coke oven gas. It is of the cross-fired automatic type, in which the air only is regenerated, the gas being preheated.

Continuous Success . . .
Heating Economics . . .

Modern design, robust construction, economical working, and close control of temperatures and atmosphere are leading features of Priest Furnaces. The illustration shows one of many furnaces recently installed in Industrial Plants of the most modern type; in all cases with satisfactory results.

LONGLANDS : MIDDLESBROUGH

BA STANDARD QUALITY

is the standard by which aluminium is judged.

The British Aluminium Company's methods of manufacture embody a system of control at every stage based on the latest scientific knowledge. Fully equipped research and testing laboratories devote their whole activity to the improvement of the product and the maintenance of quality.

Aluminium and its alloys are supplied by the Company in all forms; in ingots and billets for casting, extruding, or rolling purposes, and in the form of sheet, strip, circles, wire, tubes, bar and extruded sections. In any application of aluminium the Company's Technical Staff can advise on the most suitable grade of metal or alloy for the purpose and the best methods of manufacture.

THE **British Aluminium** CO. LTD

Head Office:
ADELAIDE HOUSE
LONDON :: :: E.C.4

Telephone: Mansion House 5561.
Telegrams: "Cryolite, Bilgate, London."

British Representatives: SPANNAGEL LTD., 13-15, OLD QUEEN STREET, WESTMINSTER, LONDON, S.W.1.

One coat of paint made with 'NORAL' Aluminium paste obliterates any ground

The perfectly smooth 'leafed' surface of an aluminium paint made with 'NORAL' paste gives it an opacity which obscures the colour of any underlying surface. Such a paint may be applied to wood, metal, plaster, or concrete, as a priming coat, to keep out the damp and to resist fumes. As a top coat it adds brightness to dark interiors, reflecting up to 75% of light. The peculiar metallic construction of aluminium paint is in the nature of an 'armour-plating.' It is extremely robust and will resist corrosion when applied to metals.

The lightness of aluminium paint is also in its favour. It is one-half the weight of leaded paint. Its heat reflectivity is invaluable for storage tanks and surfaces exposed to the sun.

Please consult our Advisory Service for full data on the use of aluminium paint.

When selecting Aluminium Paint, specify one made with NORAL PASTE—the base of the best aluminium paints

NORTHERN ALUMINIUM *Co. Ltd.*

BUSH HOUSE, ALDWYCH, LONDON, W.C.2 *Telephone:* TEMPLE BAR 8844 *Telegrams:* NORALUCO, BUSH, LONDON

and at BANBURY, BIRMINGHAM, BRISTOL, COVENTRY, GLASGOW, MANCHESTER, NEWCASTLE-ON-TYNE & SHEFFIELD

P.U.2

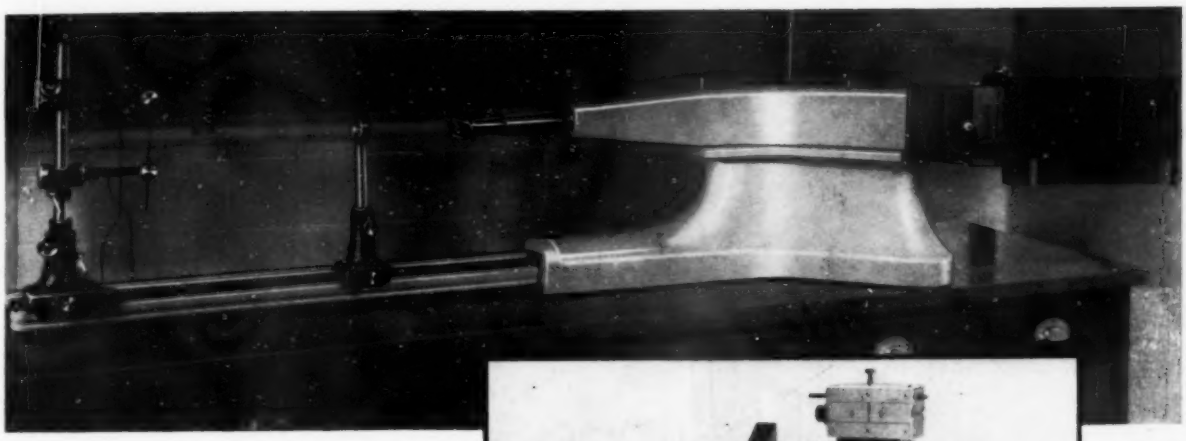
BARROW STEEL

Open Hearth Acid and Alloy Steels for Forging, Machining and general purposes. Supplied in Blooms, Billets, Slabs, Rounds, Squares, Flats, Hexagons and Special Sections to individual requirements.

All classes of Steel to comply with War Office, Admiralty, Air Ministry and British Standard Specifications; selected Steels to B.S.S. 256 and 351.

BARROW HÆMATITE STEEL CO.
BARROW-IN-FURNESS, ENGLAND

The first Photoelectric Microphotometer of its type in this country . . .



. . . for Analysis of Light Alloys

Installed at the works of

BIRMETALS LTD., BIRMINGHAM

Birmetals Ltd. possess the most complete spectrographic equipment yet installed in this country for the analysis of light alloys. It is used for the quantitative analysis of metals to a high degree of accuracy and includes a Medium Quartz Spectrograph and a Non-Recording Photoelectric Microphotometer of the most advanced design.

At Birmetals' works specimens of all metals used are excited in an arc or spark and the light emitted is analysed by the spectrograph into lines on a spectrographic plate. The positions of these lines form a complete statement of the constituent metals and the photographic densities measure the percentages of the metals. These intensities are measured rapidly and accurately by means of the microphotometer.

This equipment illustrates but one instance of the rigid routine control exercised at all stages in the works of Birmetals Ltd., to ensure absolute precision accuracy in the manufacture of sheet, extruded sections, etc., in the strong, light alloys including "Elektron."

BIRMETALS

A COMPONENT COMPANY OF BIRMID INDUSTRIES LTD.

BIRMETALS LIMITED · WOODGATE · QUINTON · BIRMINGHAM

T.G.S.

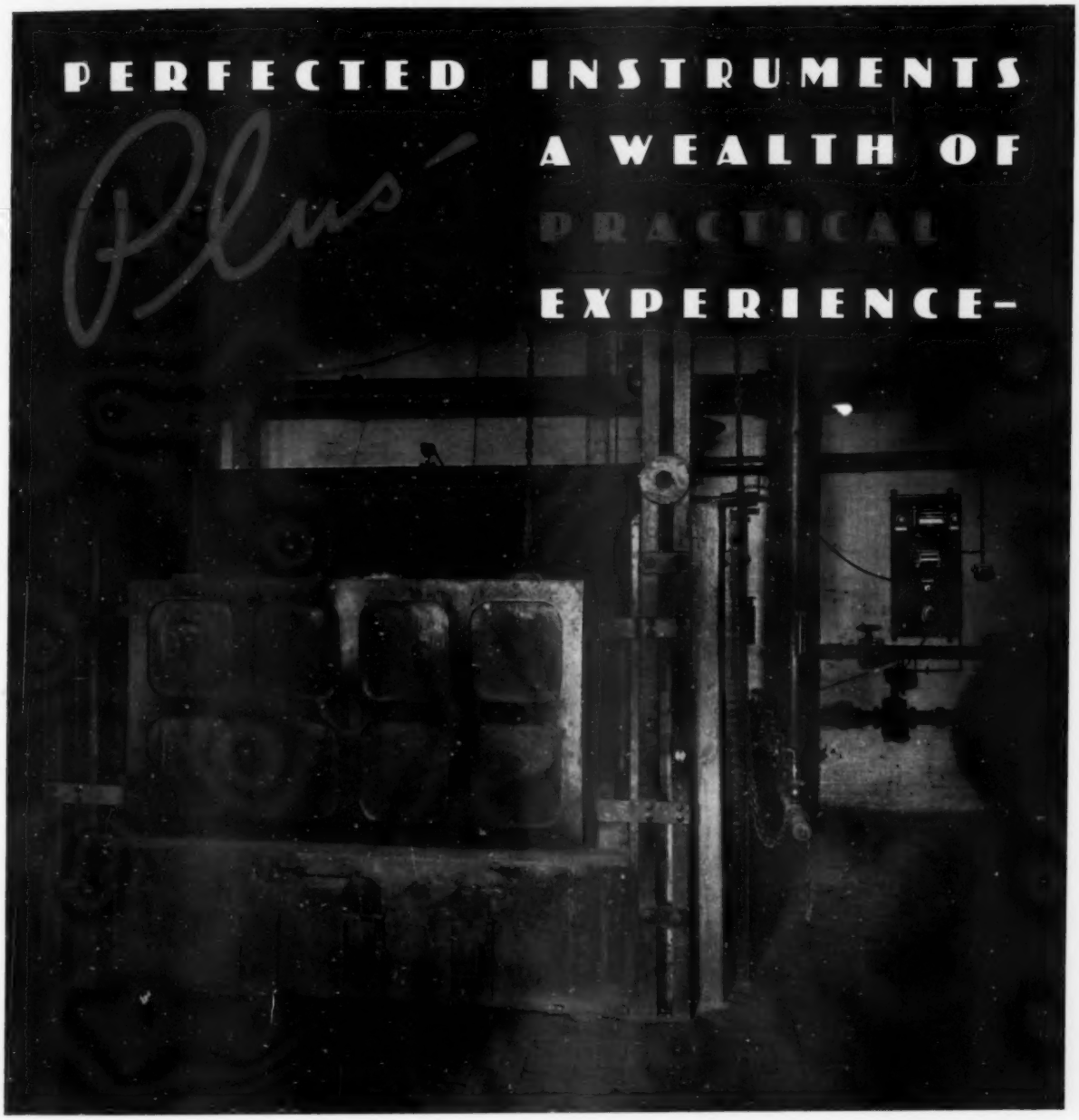
ACCURACY AT ALVIS

"BIRLEC" FURNACES are employed at the Alvis Aero Engine Factory for every heat treatment operation—

Carburising	**Tool Hardening**
Reheating	**Nitriding**
Tempering	**Stabilising**

The significance of this fact needs no stressing, and we have nothing to add beyond suggesting that YOU will be in excellent company in consulting "BIRLEC" on YOUR heat treatment problems.

BIRMINGHAM ELECTRIC FURNACES LTD., ERDINGTON, BIRMINGHAM.



There is no substitute for practical experience in automatic furnace temperature (and atmosphere) control. The performance of the "best" equipment is wholly dependent upon correct application—demanding a thorough knowledge of furnace design and reaction, heat treatment processes and their time/temperature cycles.

In Electroflo automatic control you secure perfected control equipment plus the widest practical experience—evidenced by hundreds of installations made during the past ten years on all types of heat treatment furnaces and processes.

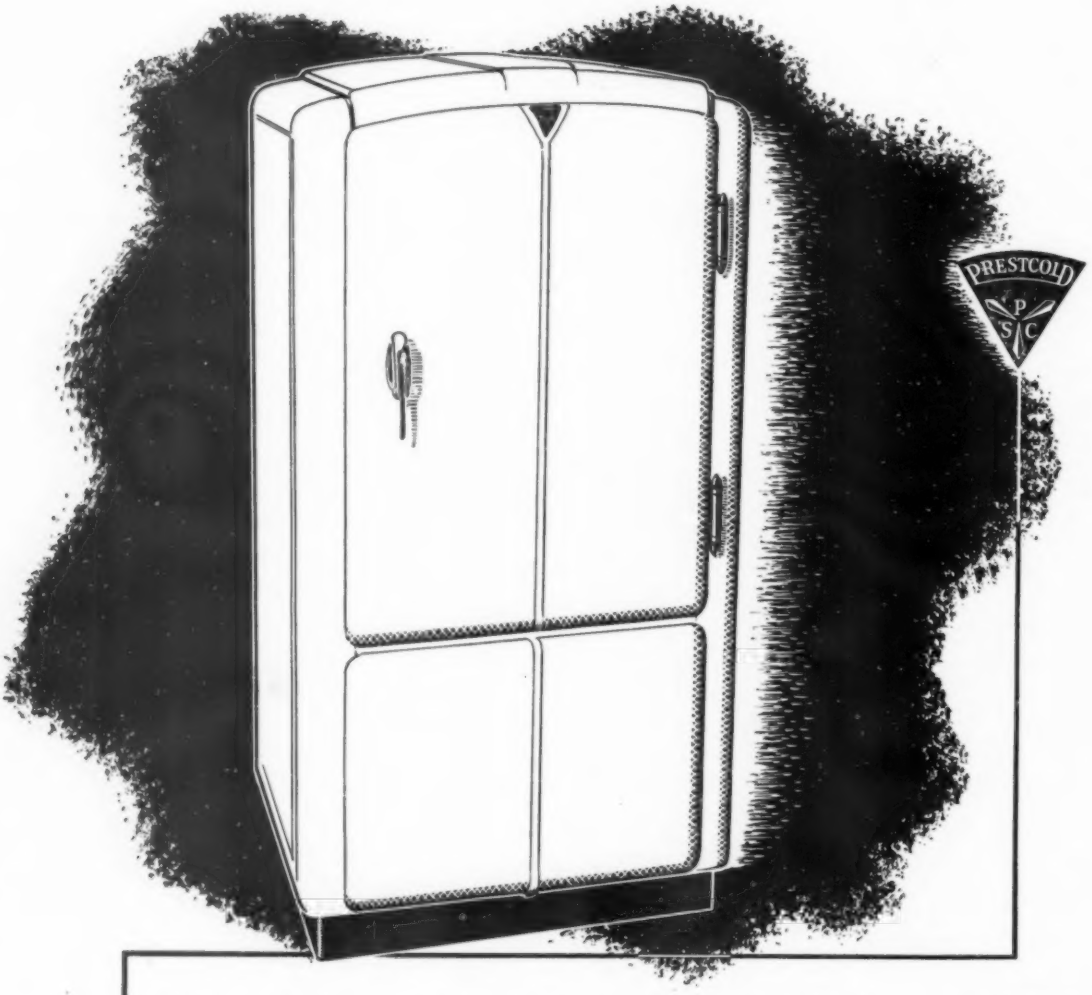
Illustrated is one of the first gas-fired furnaces in Great Britain to be successfully controlled automatically. The installation was made in July 1929 and has been in continuous use since. The extensive tests made on this furnace by Dr. C. M. Walters of The City of Birmingham Gas Department proved (as reported to The Institute of Fuel on May 14th 1930) that with automatic control of the gas supply alone there was a fuel saving of 19.4% and an increase in furnace throughput of 37%. Automatic control of the gas and secondary air increased the fuel saving to 22% and the throughput to 53%, while improving the product treatment.

PLAY SAFE—BUY EXPERIENCE AS WELL AS CONTROL INSTRUMENTS —THROUGH ELECTROFLO.

ELECTROFLO
Automatic CONTROL
FOR ALL TYPES OF HEAT TREATMENT FURNACES

Advt. of: ELECTROFLO METERS CO. LTD. PARK ROYAL, LONDON, N.W.10

FAMOUS FIRMS WHO USE THE 'CASSEL' PROCESSES OF HEAT TREATMENT . . .



PRESSED STEEL COMPANY LIMITED

The effective life of a machine depends on the durability of its moving parts. No one realises this better than the makers of Prestcold Refrigerators. To ensure lasting efficiency, they use 'Cassel' heat treatment for all compressor components. Numerous other manufacturers acknowledge the value of 'Cassel' processes for the treatment of steel parts when complete reliability, smooth working, and prolonged resistance to wear and tear are essential factors. 'Cassel' heat treatment is fully explained to you in literature which is free on request.

'CASSEL' PROCESSES OF HEAT TREATMENT

IMPERIAL CHEMICAL INDUSTRIES LTD : DEPT. C.6, IMPERIAL CHEMICAL HOUSE : LONDON : S.W.1

M.4

DEMAG

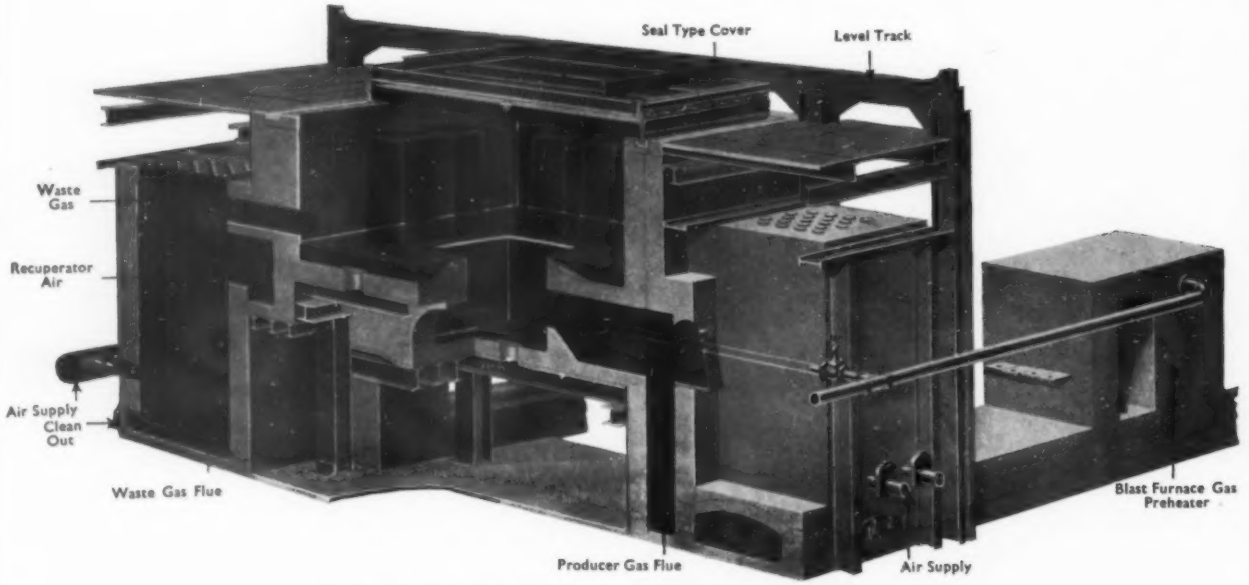
Steelworks Plants

We design and build complete Steelworks Plants, i.e., Open-hearth, Basic Bessemer or Electric Steelworks, with all accessory equipments, auxiliary machines, cranes, and transporting plants.

P. HEUSER, 119, VICTORIA STREET, LONDON, S.W. 1

K.T.G.-AMCO RECUPERATIVE SOAKING PIT

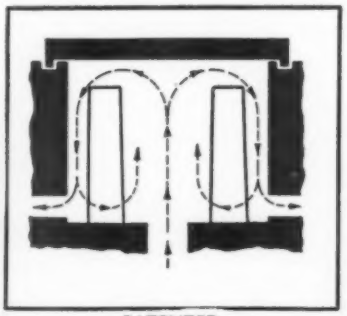
Patented and Patents Pending



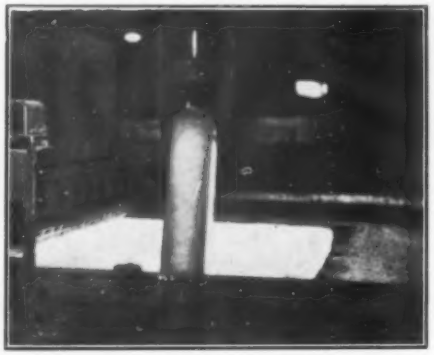
OPERATING ADVANTAGES

UNIFORM HEATING—controlled flame parallel with long axis of ingots : better steel, shorter cropping.
WASHING ELIMINATED—correct fuel application automatically regulated.
BOTTOM MAKING WEEKLY—saves coke and labour. ADDS UP TO ONE EXTRA HEAT DAILY.
INCREASED TONNAGE—charged capacity is increased up to 100% when compared with existing pits.
SEALED COVER—CRANE TYPE MOTORISED CARRIAGE.
Automatic fuel and air regulation with cover movements—saves fuel—speeds operation.

CONTROLLED HEAT CIRCULATION
character of scale controlled.
DEPENDABLE RECUPERATION.



FUEL SYSTEM FULLY AUTOMATIC
draught control.
NO MANUAL ADJUSTMENTS.

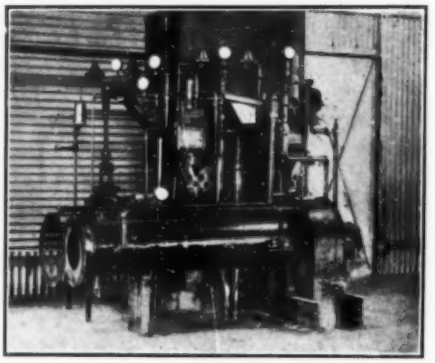


Open Pit

PATENTED

KTG

USES ALL FUELS



Automatic Draught and Air Ratio Equipment

Embodies the best known combustion, metallurgical and mechanical practice.

WRITE FOR FULL PARTICULARS TO :

KING, TAUDEVIN & GREGSON LTD.

Furnace and Gas Plant Engineers,

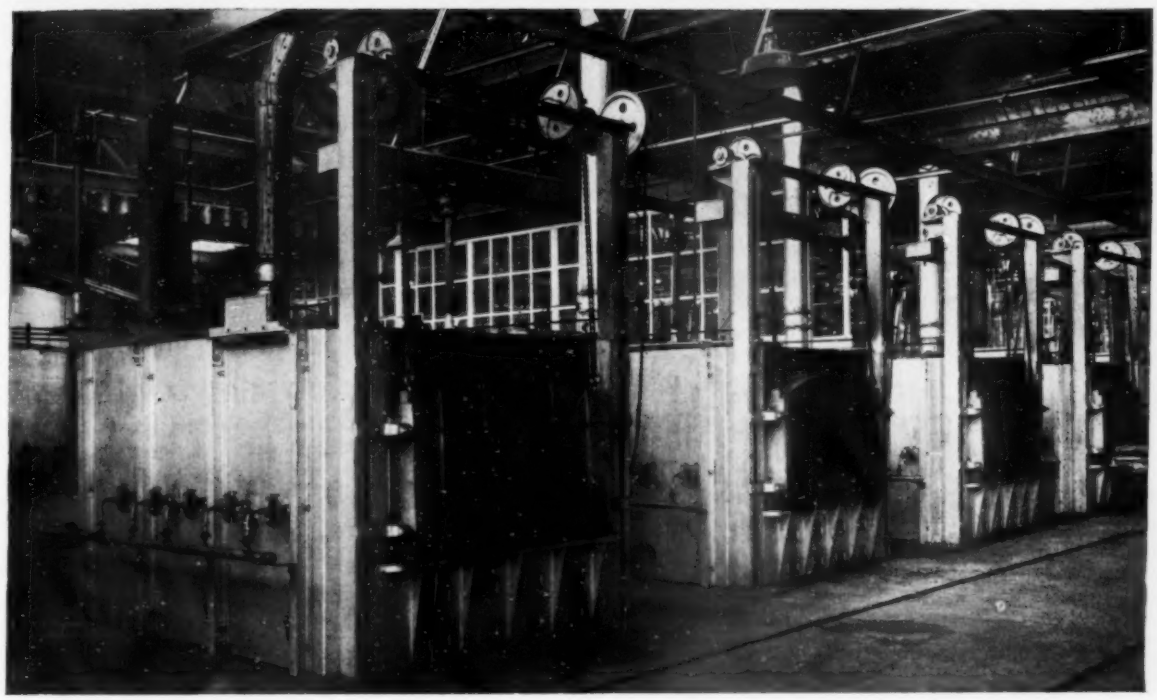
Melbourne Chambers, Cambridge Street,

Telephone :
Sheffield 21753.

SHEFFIELD 1.

Telegrams :
"Pyro, Sheffield."

GIBBONS FURNACES



Four of a group of ten Gibbons' town's gas-fired carburizing furnaces, fitted with Electroflo automatic control, at the works of Messrs. Wolseley Motors (1927) Ltd.

Reliable results sought in heat-treating practice depend upon the proper combination of the man, the furnace, and the material. Good material is entitled to proper treatment in good furnaces, and both should have the services of good men.

No two cases are alike, and no type of furnace has a monopoly on uniformity of heating or economy in operation; for this reason we, as specialists, design heat-treatment furnaces to suit your particular conditions and products; in this way reliable results can be assured, with the utmost economy.

For all types of burners and small heat-treatment furnaces *write to our associated company :—*

THERMIC,
Equipment & Engineering Co. Ltd.
Foundry Yard,
Salmon Street,
PRESTON.

Telephone: 3782 PRESTON.
Telegrams: THERMIC.

GIBBONS BROS LTD
DUDLEY :: WORCS.

ROBERTSONS *British*

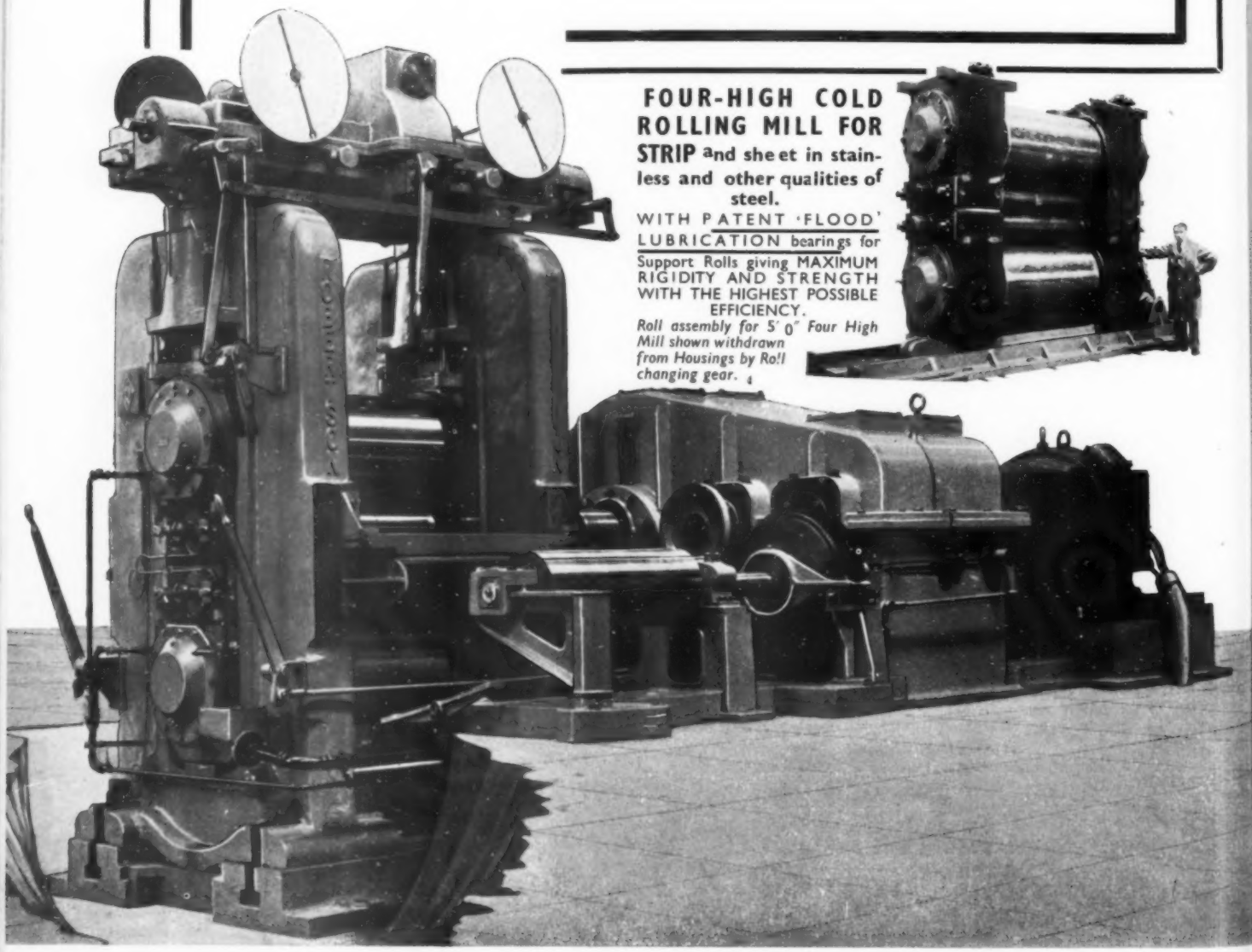
renowned for mills that give continuous accuracy . . .

To the patriotic urge of Buy British and the assurance from the highest quality that is conveyed by the words "British Built," are added many sound reasons for buying Robertson's British Rolling Mills and accessories. As designers and builders of British Rolling Mills, we are often called into consultation for the application of rolling mills and accessories for special purposes. We have an intimate knowledge of the varying local methods and habits of British rolling mills. We are conversant with rolling mill technique in many countries, our international experience has resulted in the design of rolling mills and accessories that do give continual satisfaction. We invite you to make use of the services of our technical staff, who are always ready to advise you in any difficult jobs.

FOUR-HIGH COLD ROLLING MILL FOR STRIP and sheet in stainless and other qualities of steel.

WITH PATENT 'FLOOD' LUBRICATION bearings for Support Rolls giving MAXIMUM RIGIDITY AND STRENGTH WITH THE HIGHEST POSSIBLE EFFICIENCY.

Roll assembly for 5' 0" Four High Mill shown withdrawn from Housings by Roll changing gear.



W. H. A. Robertson & Co. Ltd.
Telegrams : WHARCO

Bedford
Telephone : 4171

THE FACTORIES* ACT OF 1937

lays down definite rules for employers

about

HEATING AND VENTILATION

LIGHTING

WASHROOMS

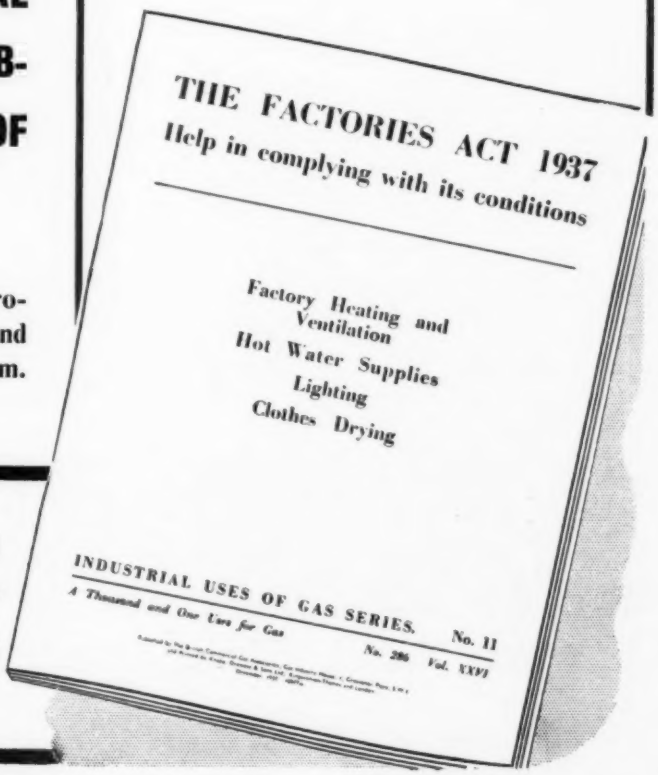
CLOTHES-DRYING

* For the purposes of the Act the word 'Factory' is interpreted to cover a great variety of work places, such as institutional laundries, vehicle repair shops, workshops of theatrical costumiers, and sections of the premises of many other British trades. Does your trade come under the Factories Act?

Do you know what these rules are? Are you complying with them? Are you complying with them in the best and most economical way?

THE BRITISH COMMERCIAL GAS ASSOCIATION HAS PUBLISHED A SPECIAL BOOK OF EXPLANATION.

This book sets out all the relevant provisions of the Act simply and shortly, and tells you how best to comply with them.

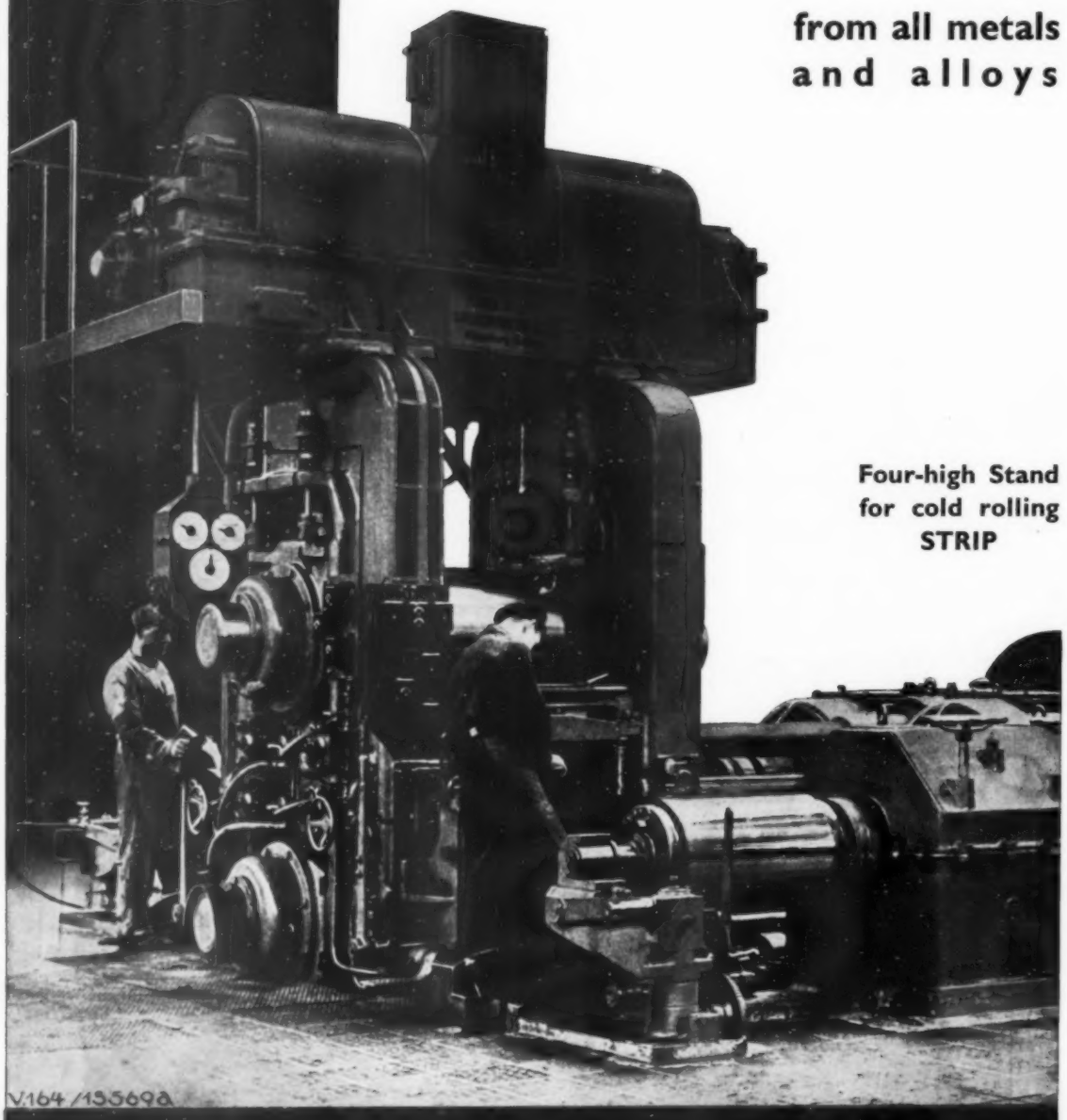

THE FACTORIES ACT 1937
Help in complying with its conditions
Factory Heating and Ventilation
Hot Water Supplies
Lighting
Clothes Drying
INDUSTRIAL USES OF GAS SERIES. No. 11
A Thousand and One Uses for Gas

On receipt of your trade card, we shall be glad to send you this book free by return. Write to The British Commercial Gas Association, Gas Industry House, 1 Grosvenor Place, London, S.W.1.

COLD ROLLING MILLS

for SHEETS and STRIP

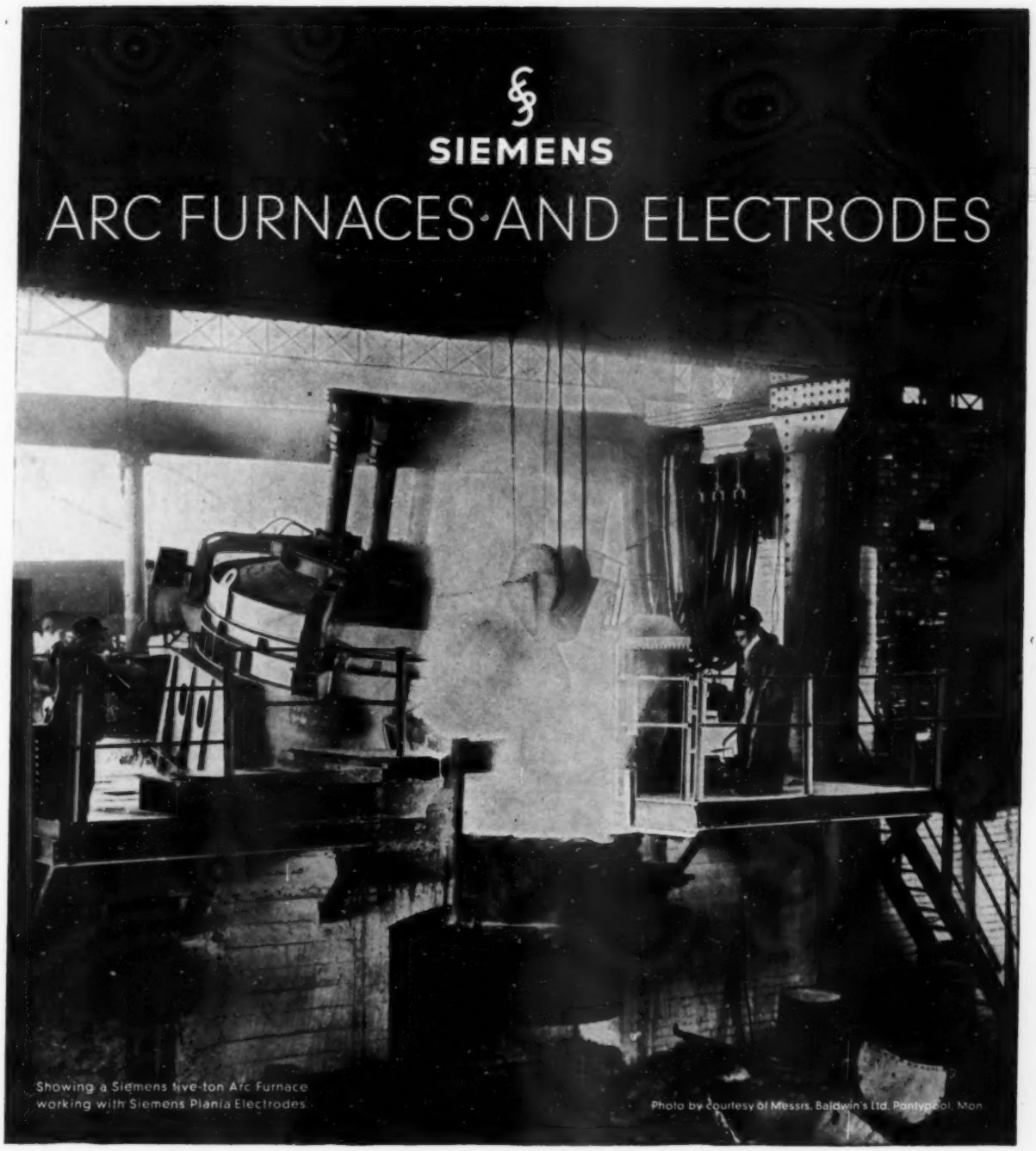
from all metals and alloys



Four-high Stand for cold rolling STRIP

FRIED. KRUPP GRUSONWERK
AKTIENGESELLSCHAFT · MAGDEBURG

Sole Agents in Great Britain JOHN ROLLAND & CO., LTD., Abbey House, 2, Victoria St., LONDON, S.W.I. Tel.: Abbey 3928


SIEMENS
ARC FURNACES AND ELECTRODES
Showing a Siemens five-ton Arc Furnace working with Siemens Plania Electrodes
Photo by courtesy of Messrs. Baldwin's Ltd. Pontypool, Mon

More than 200

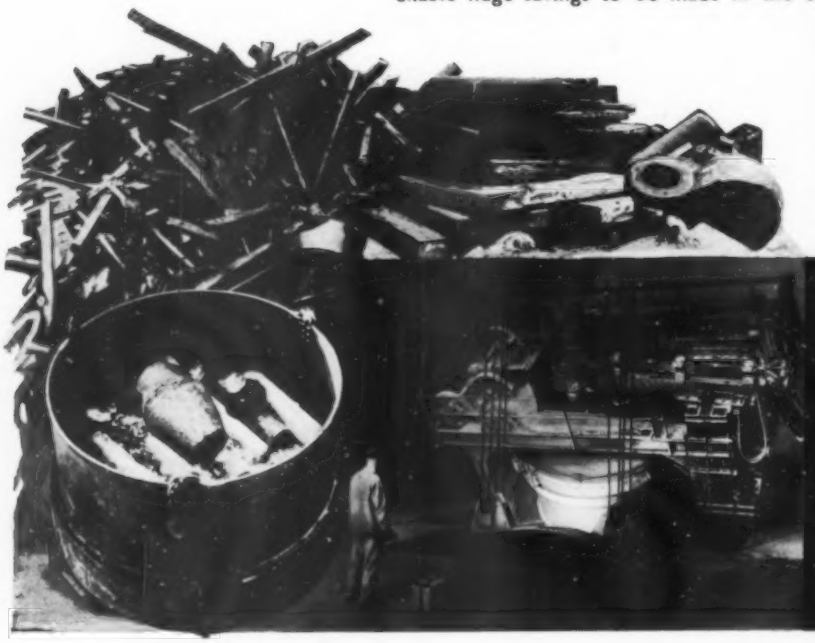
Siemens Melting and Reduction Furnaces are working satisfactorily and economically with SIEMENS PLANIA ELECTRODES. We are in a position to supply suitable Electrodes for any Electro-Metallurgical and Electro-Chemical Process.

SIEMENS-SCHUCKERT (GREAT BRITAIN) LTD · GREAT WEST ROAD · BRENTFORD · MIDDLESEX

ELECTRIC STEEL FURNACES

with Basket Charging and Vessel Turning Gear

enable huge savings to be made in the costs of breaking up and charging scrap



This Bulky Scrap

is brought along from the scrapyard and inserted just as it is in the furnace by our patented charging basket. The basket shown in the illustration contains a charge of 15 tons, made up of steel rolls and tops. The charge is not dropped on to the hearth of the furnace but laid gently down on to it without the slightest bump.

Further particulars may be had on application to :

Demag-Elektrostahl
G M B H
DUISBURG

PICTURES have an international appeal knowing no bounds of language.

They tell their story quickly and convincingly —If they are good pictures.

We have specialised in engineering subjects for many years and our artists appreciate the engineers' outlook. They can put life and action into otherwise dull and uninteresting photographs in a manner that pleases the eye without offending the engineers' sense of correctness.

For your next photographs and drawings of machines, plant etc., consult, without obligation,

INDUSTRIAL ART SERVICES LTD

INDUSTRIAL ART
SERVICES LTD
21, ALBION ST.
GAYTHORN
MANCHESTER.

Telephone CEN 2574

For Rigid Specifications and in Superior Quality Steels

use

" Saudamet "

Alloys

▼

MANGANESE

various Manganese alloys and metals

▼

SILICO-MANGANESE

alloys of Silicon and Manganese

▼

ZIRCONIUM

various Zirconium alloys

▼

CALCIUM-ALLOYS

and other electric furnace products

▼

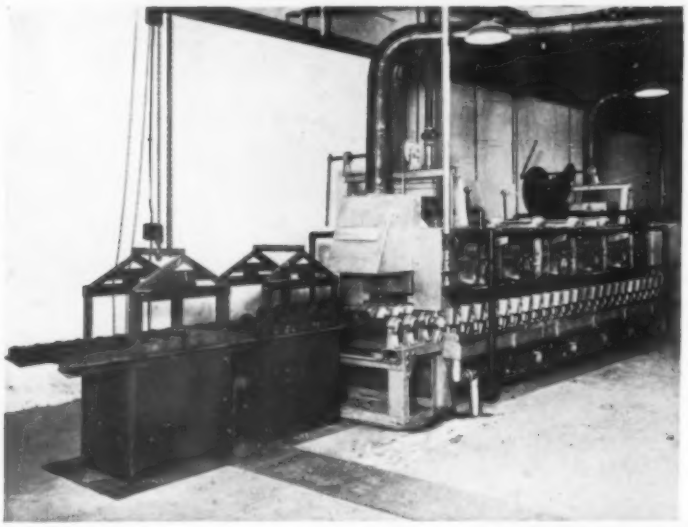
ELECTRIC FURNACE PRODUCTS Co. Ltd

Smelting Works at

Sauda

NORWAY

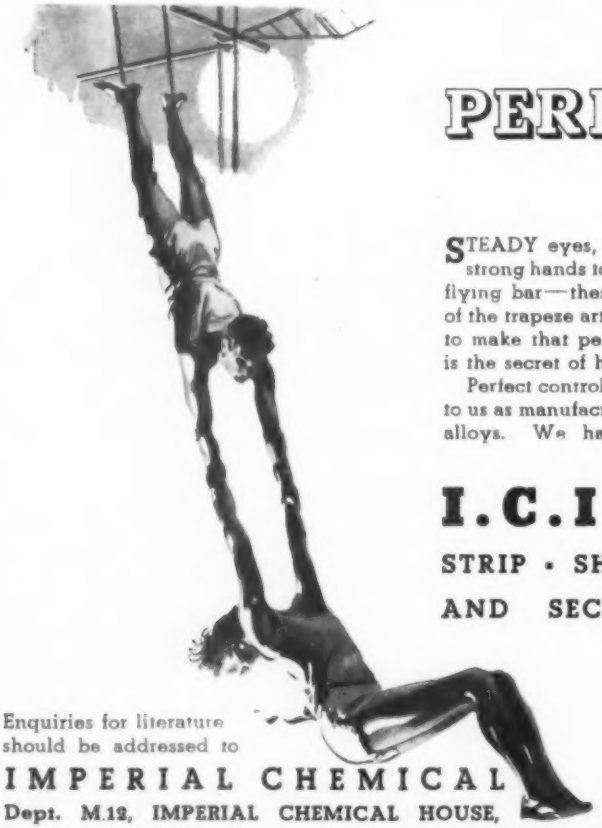
INCANDESCENT HEAT
SPECIAL PURPOSE FURNACES



Gas-fired refractory-roller hearth furnace for general heat treatment of forgings, as installed in the works of a leading British commercial vehicle manufacturer. Provided with oil and water quenching tanks.

Designers and manufacturers of every type of furnace for all industries. Special Purpose furnaces of every description for all fuels and for either continuous or intermittent working. If you have a heat treatment problem send for an Incandescent Engineer to solve your difficulties

INCANDESCENT HEAT Co. Ltd.
CORNWALL ROAD, SMETHWICK, BIRMINGHAM.
"Phone: SMETHWICK 0675-6-7 "Grams: Kepwit, Birmingham
LONDON OFFICE: NORTHERN OFFICE & WORKS:
16, Grosvenor Place, S.W.1 Soho Works, City Road, Manchester 15
"Phone: Victoria 7803. "Phone: Central 2548.
"Grams: Incandescent, Knights, London.



PERFECT CONTROL

STEADY eyes, wrists of steel, and strong hands to grasp and hold the flying bar—these are the attributes of the trapeze artiste. They combine to make that perfect control which is the secret of his success.

Perfect control is just as necessary to us as manufacturers of non-ferrous alloys. We have ensured it by careful attention at every stage of manufacture, by constant research work, by employing only the finest machinery and skilled labour. The result is reflected in the perfection of our non-ferrous alloys — in sheet, strip, tubes, plates, wire, rods, sections — and their unrivalled reputation.

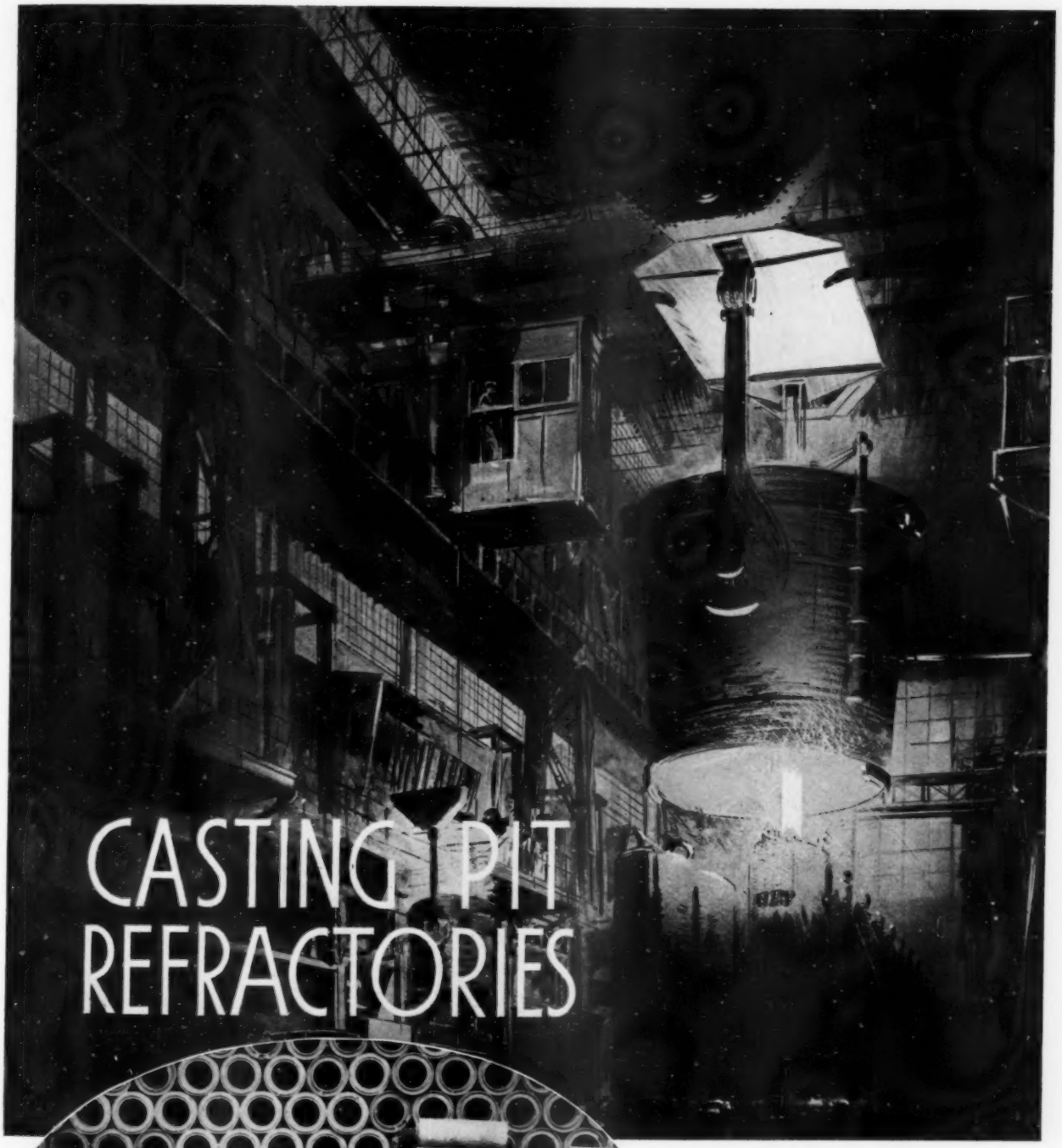
I.C.I. METALS LTD.

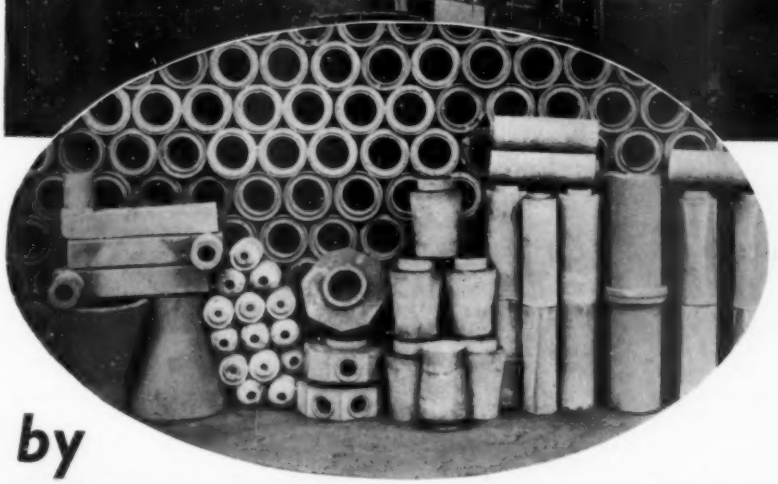
STRIP • SHEET • TUBES • PLATES • WIRE RODS AND SECTIONS IN NON-FERROUS ALLOYS

Enquiries for literature should be addressed to

IMPERIAL CHEMICAL INDUSTRIES LIMITED

Dept. M.12, IMPERIAL CHEMICAL HOUSE, MILLBANK LONDON, S.W.1. Sales Offices at: Belfast, Birmingham, Bradford, Bristol, Dublin, Glasgow, Hull, Liverpool, London, Manchester, Newcastle, Shrewsbury, Swansea



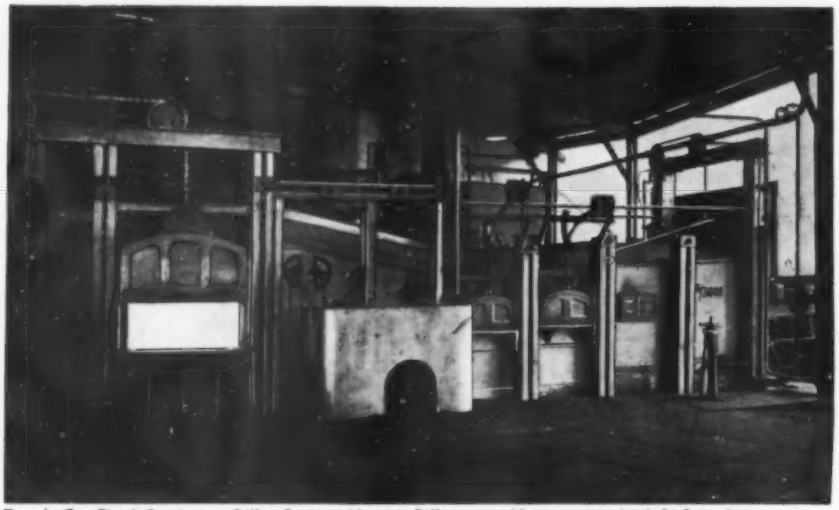


NOZZLES
STOPPERS
SLEEVES
LADLES &
RUNNER
BKS. ETC.

by

THOMAS MARSHALL & Co. (LOXLEY) LTD. LOXLEY, Nr. SHEFFIELD

DOWSON & MASON
GAS PLANTS & FURNACES



Town's Gas-Fired Continuous Billet Furnace Heating Billets up to 12 in. square by 6 ft. 0 in. long.

Specialists in the manufacture of :

CLEAN GAS PRODUCER PLANTS using coke, anthracite or bituminous fuel.

FURNACES OF ANY TYPE, fired by gas, oil or solid fuel.

OVER 50 YEARS' EXPERIENCE

If you have a Heating Problem consult the

DOWSON & MASON GAS PLANT COMPANY LTD.

ALMA WORKS LEVENSHULME MANCHESTER

When

METALS are discussed, whether Ferrous or Non-Ferrous, Executives refer to

"METALLURGIA"

THE editorial responsible for METALLURGIA offers only the best, and this prestige is retained by publishing views contributed by world-wide authorities on every aspect of ferrous and non-ferrous metallurgy.

The quality of the literary pages of METALLURGIA demands attention, therefore METALLURGIA is outstanding as an Advertising Medium for the industry it claims to represent.

Make use of the advantages it offers, and its subscribers at home and overseas, which include a wide audience of responsible executives, will familiarise themselves with your products.

Published on the 16th of every month by

THE KENNEDY PRESS LTD., 21, Albion Street, Gaythorn, MANCHESTER 1

Telephone : Central 0098 Telegrams : "Kenpred, Manchester"

UNGERER

is building as sole speciality

Roller Sheet Levellers

which produce results as illustrated in all metals: strips, sheets or plates up to 10 feet wide by ½ inch in thickness.

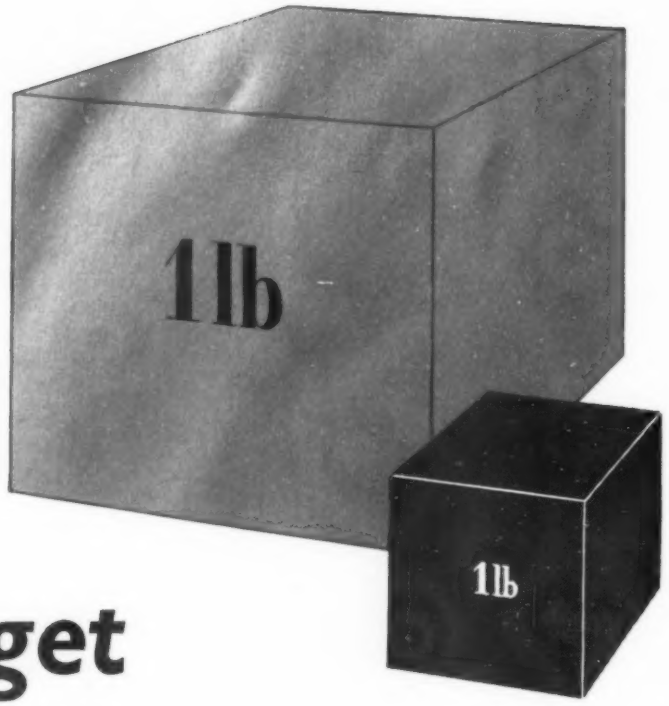
MOST MODERN CONSTRUCTION. PATENTED IN ALL COUNTRIES.

ESTABL. UNGERER 1895

KARL FR. UNGERER · ENGINEERING WORKS, PFORZHEIM-BRÖTZINGEN, GERMANY

Sole Agents in Great Britain :
INCANDESCENT HEAT CO. LTD.,
SMETHWICK, BIRMINGHAM.

Technical Representative :
EMIL HAAG, 197, HOLLY ROAD,
BIRMINGHAM 20.



You get value for your money with Aluminium

Which is the heavier — a pound of feathers or a pound of lead? There is no reason for you to get caught by this. *Per pound* aluminium costs more — but *per finished casting?* That is a very different matter.

Because aluminium goes approximately three times as far per pound as most other metals, and is easier to machine, the finished casting often costs less; and if there is a fractional extra cost, you get in return all the advantages that only aluminium can provide.

It will pay to take a look round your foundry to see if there are any jobs that could be better cast in aluminium. Our technical department will be glad to help in the solution of any problem that may arise. *Aluminium Union Limited, Bush House, London, W.C.2. Tel.: Temple Bar 8844.*

ALUMINIUM UNION LIMITED

HIGH PURITY ALUMINIUM INGOT · FOUNDRY ALLOYS

METALLURGIA

The British Journal of Metals

(Incorporating The Metallurgical Engineer.)

★ The source of all matter extracted from this Journal must be duly acknowledged; it is copyright. ★

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

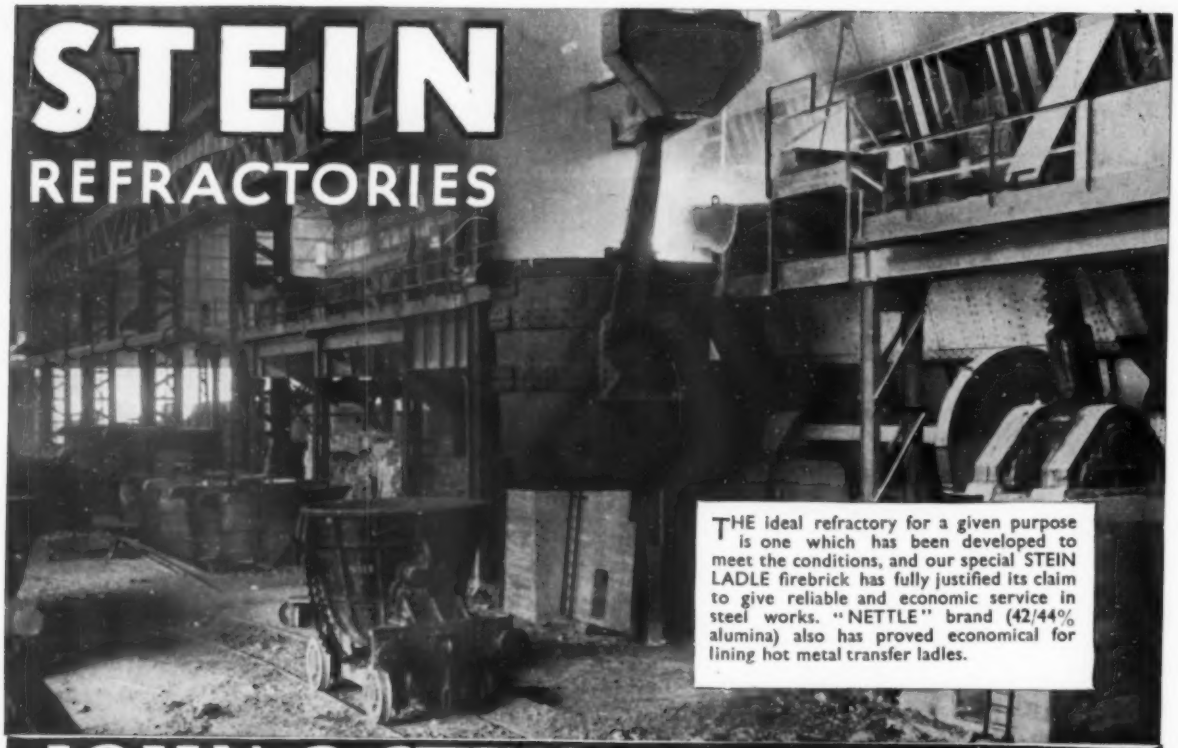
PRINCIPAL CONTENTS IN THIS ISSUE:

	Page
An Oxygen-free Copper Development. *As a result of considerable study and prolonged tests a high conductivity copper, substantially free from oxygen, has been evolved, and in this article comparisons are made between this copper and tough-pitch copper.*	207–209
The Thermo-chemistry of Alloys	210
Rearmament and Industry	211
Forthcoming Meetings	212
Strength Properties of Rolled Mild Steel Sections. By G. Welter and M. S. Wolagiewicz. *In acceptance tests on structural steel, regard should be given to changes in mechanical properties, which may be appreciable, according to the position of the test-pieces in the rolled sections. Tests on girders are discussed which give useful information in connection with the use of these structural shapes, and on the need for greater care in the casting and rolling operations.*	213–217
Strength of Nickel-Chromium Alloys at High Temperatures	218
The Protection of Aluminium Base Alloys Against Outside Atmospheric Exposure. By E. Armstrong. *The advantages of synthetic organic finishing media for the protection of aluminium base alloys are discussed. Methods of cleaning and applying the finish are reviewed, and the merits of certain classes of finishing media are emphasised, particularly with regard to finishing time and production, under conditions of atmospheric exposure.*	219–222
Fuels of To-day and To-morrow	222
Controlling Controlled Atmospheres. *Accuracy in the measurement of temperature and close control of the rate of heating and cooling have long been the sole criteria of heat-treating, but a fast-growing fund of knowledge on the subject emphasises the importance of furnace atmosphere, and in this article is described a recent development for measuring and recording furnace atmospheres.*	223–224
The Metallurgical Inspection of Steel. By J. S. G. Primrose. *There is an ever-increasing need for the application of metallurgical inspection on steel in all its forms; some outstanding examples, which can be taken as representative and significant, are discussed.*	225–226
Recent Developments in Tantalum and Columbium	226
High Speed Strip Rolling. By C. E. Davies, M.I.Mech.E. *Progress towards high rolling speeds has been remarkable during the last 10 years, especially in Britain, and the general trend of modern practice is reviewed.*	227–228
Lithium—an Alloying Element and De-Oxidising Agent. By Stephen Coleman	228
Reviews of Current Literature. *International control in the non-ferrous metals. Tin researches. Principles of powder metallurgy. Casting and finishing aluminium.*	229–230
Cartellisation in the World Aluminium Industry. Part III. By Robert J. Anderson, D.Sc. *The disparity between the extensive possibilities of production and the limited possibilities of consumption has long presented an economic problem, and the cartel movement is an effort to control producing and marketing activities.*	231–233
United States Aluminium Industry in 1937	233
"K" Monel Metal	234
Deep Drawing and Pressing Problems. By J. D. Jevons, Ph.D., A.I.C. *The industrial processes by which sheet metal is formed into shape are discussed.*	235–236
Steels and Their Utilisation for High Steam Pressures and Temperatures. By R. W. Bailey, D.Sc.	237–238
Business Notes and News	239
Metal Prices	240

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "Kenpred," Manchester. *Telephone: Central 0098.*


STEIN
REFRACTORIES
THE ideal refractory for a given purpose is one which has been developed to meet the conditions, and our special STEIN LADLE firebrick has fully justified its claim to give reliable and economic service in steel works. "NETTLE" brand (42/44% alumina) also has proved economical for lining hot metal transfer ladles.

JOHN G. STEIN & Co LTD BONNYBRIDGE SCOTLAND

We are exhibiting at the Empire Exhibition, Glasgow, May—October, 1938, STAND E55

Accuracy of Form is of little worth without the Basic Steel Quality!
SABEN
SABEN
SABEN
SABEN Super High Speed Steel
MILLING CUTTERS, REAMERS & DRILLS
EMBODY BOTH THESE ESSENTIALS ALLIED TO PERFECT HARDENING.
Send For our New Sectional Catalogue "G"
SANDERSON BROTHERS & NEWBOULD LIMITED
SHEFFIELD ENGLAND

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

APRIL, 1938. VOL. XVII, No. 102.

An Oxygen-Free Copper Development

As a result of considerable study and prolonged tests a high conductivity copper, substantially free from oxygen, has been evolved and is now produced on a commercial scale under the name of "Bicop." This copper has high mechanical properties and in this article comparisons are made with tough-pitch copper.

IT is a well-known fact that ordinary commercial copper contains oxygen, which is present in the form of cuprous oxide, Cu_2O. The oxygen is absorbed when copper is melted in contact with air and cuprous oxide is formed on the surface, which dissolves in the metal and, on solidification, forms a film or network surrounding the metal crystals. The cuprous oxide present in the copper offers a high resistance to the passage of an electric current, thus this impurity has a considerable influence on the conductivity of the copper. Although its effect on the mechanical properties of copper is not so marked the pressure of cuprous oxide reduces the toughness of the copper and with increasing percentages the copper becomes brittle.

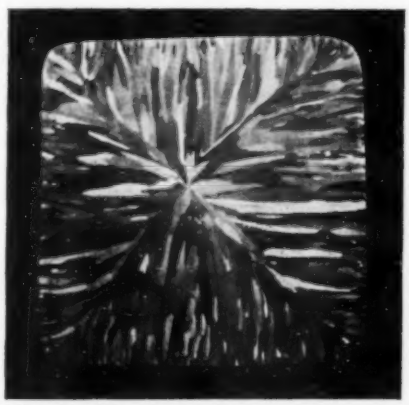


Fig. 1.—The macrostructure of a cross-section of a wirebar.

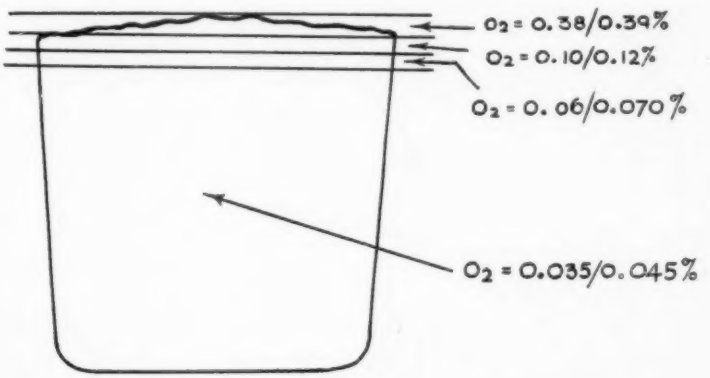


Fig. 2.—Wirebar as cast showing the approximate oxygen content at the set surface and at various levels to bulk metal.

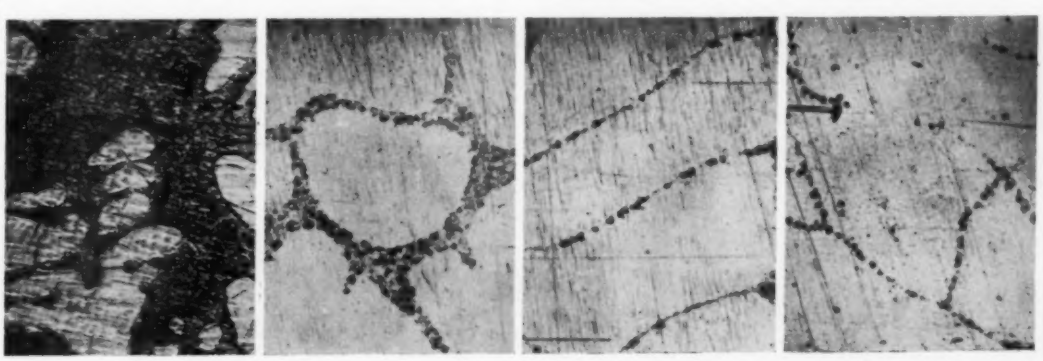
The complete removal of oxygen from copper has long been recognised as being difficult to carry out industrially, but steps are taken to reduce the oxygen content before casting the molten copper into ingots. The process usually adopted is known as "poling," by which tough-pitch copper is produced, this process, however, can be overdone in which case the copper produced will show brittle characteristics. As a result of an exhaustive investigation and a prolonged series of tests British Insulated Cables Ltd. has evolved a high conductivity copper which is substantially free from oxygen. This copper, which is registered under the name of "Bicop," is now produced on a commercial scale for use, not only where high conductivity is desirable, but where the maximum ductility, toughness, resistance to fatigue and high density are required.

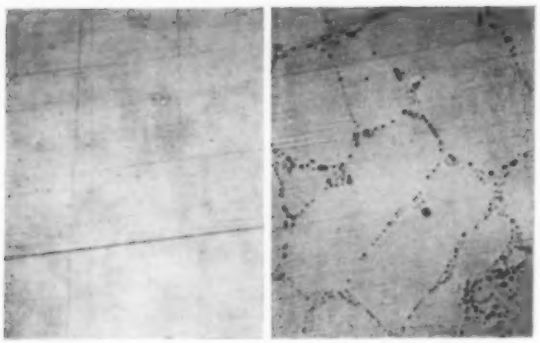
Apart from its superiority in mechanical properties over ordinary tough-pitch copper, which are shown in the test values given elsewhere in this article, an outstanding feature of this new brand copper is its immunity from embrittlement when annealed in a reducing atmosphere; tough-pitch copper, on the other hand, when annealed in a reducing atmosphere is normally rendered so brittle that its mechanical properties are substantially reduced.

This "Bicop" brand copper is produced in a special manner, under the closest supervision and control, to ensure castings of exceptional uniformity and purity. The investigation included experimental work on suitable types

Fig 3.—Photomicrographs showing the oxygen distribution in horizontally-cast tough-pitch copper wirebar. × 150.

0.38/0.39% 0.10/0.12% 0.06/0.07% 0.035/0.045%





Bicop Brand copper. Tough-pitch copper.

Fig. 4.—Photomicrographs comparing Bicop and tough-pitch copper ; specimens for the latter being taken from the area where the oxygen content is stable at approximately 0.04%. The specimens were polished but unetched. × 150.

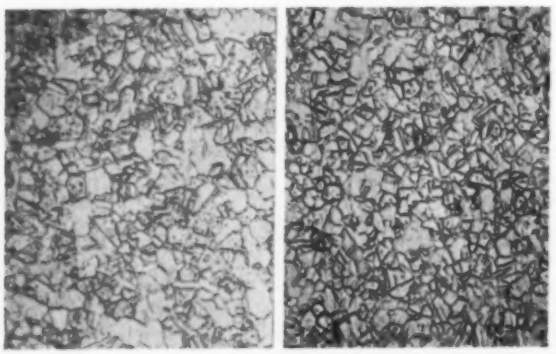
of moulds and vertical moulds of special design and size have been standardised for this special brand. The macro-structure of a cross section of a wirebar in this copper is shown in Fig. 1.

In order to present comparative mechanical and electrical values of wires produced from this new brand copper and horizontally cast tough-pitch copper, it will be profitable to show the oxygen content of ordinary horizontally cast tough-pitch copper ; for this purpose a study of a transverse section cut from a standard horizontally cast tough-pitch copper wirebar is given as an example in Figs. 2 and 3.

As previously stated the oxygen contained in tough-pitch copper is present as a definite chemical constituent cuprous oxide. Forming on the surface of the molten copper this constituent dissolves and lowers the freezing point of the copper. Although soluble in molten copper it is practically insoluble in solid copper. When copper containing this oxide freezes, crystals of pure copper are first deposited, leaving the remaining liquid richer in oxide and this continues until the eutectic composition is reached, when most of the copper has solidified and the remaining liquid lies between the crystals forming a film as shown in the photomicrographs, Fig. 3. The corrugated upper surface of the wirebar, known as the "set surface," is composed almost entirely of oxygen-rich copper, and a gradual diminution of the oxygen content obtains from the set surface downwards until a depth of approximately ½ in. and in extreme cases 1 in. is reached, when the oxygen content becomes stable at a figure nearing the desired value. The distribution of the oxygen content in a horizontally cast tough-pitch copper wirebar is shown in Fig. 2, while photomicrographs representing the different sections are shown in Fig. 3.

Fig. 5.—Photomicrographs comparing two hot-rolled rods 0.25 in. diameter. × 150. Note the absence of cuprous oxide in the specimen on the left.

Bicop Brand Copper. Tough-pitch copper.



Specimens cut from a "Bicop" copper wirebar and a horizontally cast tough-pitch copper wirebar–the latter taken from the area where the oxygen content is stable at approximately 0·04%—are shown in the polished but unetched state in Fig. 4. The absence of cuprous oxide in the specimen of the new brand copper is noteworthy, whereas the familiar intercrystalline inclusions of cuprous oxide are plainly discerned in the standard horizontally cast tough-pitch copper. In a hot-rolled rod, 0·250 in. diameter, the absence of cuprous oxide from "Bicop" copper, will be noted in Fig. 5, whilst inclusions of oxide in a coalesced state are evident in a rod produced from a standard horizontally cast tough-pitch copper. It must not be overlooked that the remnants of the set surface of the wirebar and the normal inclusions in a wire 0·097 in. diameter produced from a standard horizontally cast copper wirebar shows unequal distribution of the oxide as in Fig. 6.

It has long been known that copper containing cuprous oxide becomes brittle when it is annealed in hydrogen, and examples of brittleness of copper parts that have been exposed in service to a reducing atmosphere are numerous. It is now known that the brittleness results from the reduction of the cuprous oxide by hydrogen.

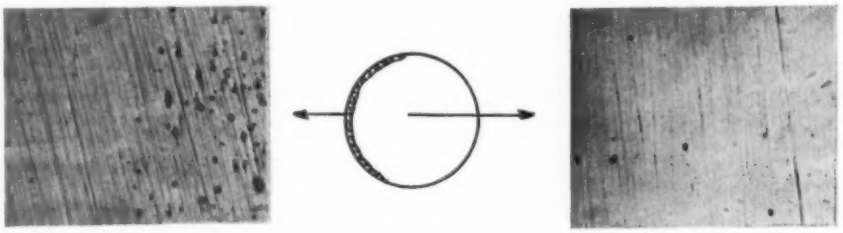
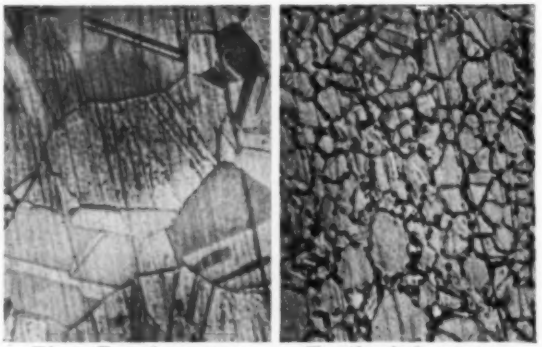


Fig. 6.—Showing remnants of a set surface of the wirebar and the normal oxide inclusions in wire 0.097 in diameter produced from standard horizontally-cast copper wirebar. ×150.



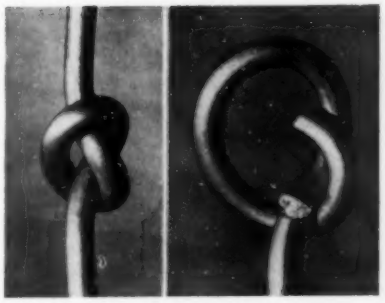
Bicop Brand copper. Tough-pitch copper.

Fig. 7.—Showing the effects of annealing in hydrogen on wires from Bicop and standard horizontally-cast copper. × 160.

The steam formed is unable to escape by diffusion and therefore forces apart the grains of the metal, causing intercrystalline cracks and fissures.[1] The effects of annealing in hydrogen wires produced from "Bicop" copper and horizontally cast tough-pitch copper are therefore of interest. As will be noted in the photomicrographs, Fig. 7, the new brand copper is sound and unaffected by the treatment, whereas the reduction of cuprous oxide in the tough-pitch copper has resulted in partial removal of the oxide between the crystal boundaries, causing sponginess in the metal and hence excessive unsoundness and brittleness which has ruined its mechanical properties.

[1] "Impurities in Metals," by Dr. Colin J. Smithells. Champan and Hall Ltd.

The mechanical and electrical values of wires, 0·081 in. diameter, produced from "Bicop" copper are compared with those from tough-pitch copper given in Tables I to IV; these show various properties in the hard-drawn state, and also subsequent to commercial bright annealing and annealing in hydrogen. From the torsion values given in Table I, the ductility of the new brand copper in both hard and bright annealed conditions is very marked. After annealing in hydrogen for a period of 30 min. at 850° C. this copper is still ductile, whereas tough-pitch copper is very brittle. Results of bend tests are given in Table II; here again the new brand copper shows marked superiority, the effect of annealing in hydrogen in particular showing serious embrittlement of the tough-pitch copper. As far as tensile strength is concerned the results of tests given in Table III show little difference. No appreciable difference is shown in the electrical conductivity, but reference to Table IV shows that the values given by both coppers meet all standard specifications.



Bicop Brand copper. Tough-pitch copper.

Fig. 8.—Showing the ductility of copper wire samples after annealing in hydrogen. ×5.

Fig. 9.—Shows the result of twisting to destruction specimens of square wire, on the left Bicop, and right tough-pitch copper. × 3.

Fig. 10.—The reduction in area of a tensile fracture in hard-drawn wire in Bicop (left), and tough-pitch copper. × 6.

TABLE I.

Torsion Test.			Twists in 6 in.		
"Bicop" Brand CU.			Tough-pitch Copper.		
Hard	Bright Annealed	H2 Annealed	Hard	Bright Annealed	H2 Annealed
108	167	119	45	105	5
103	113	115	43	97	12
122	138	134	38	85	9
126	124	98	42	94	6

TABLE II.

Bend Test.			90° Bends over 5 m/m. radius		
"Bicop" Brand Copper.			Tough-pitch Copper		
Hard	Bright Annealed	H2 Annealed	Hard	Bright Annealed	H2 Annealed
49	78	66	16	46	4
42	66	62	20	52	2
48	73	95	24	50	1
37	71	63	18	45	3

TABLE III.

Tensile Strength in Tons per Square Inch.

"Bicop" Brand Copper.		Tough-pitch Copper.	
Hard	Commercially Bright Annealed	Hard	Commercially Bright Annealed
31·37	16·80	30·71	16·60
31·58	16·45	30·44	16·80
31·80	16·35	30·99	16·80
31·11	16·35	30·50	16·30
31·46	16·88	31·12	16·40
30·41	16·75	31·13	16·80
31·98	16·52	30·78	16·60
32·15	16·35	30·54	16·65
31·98	16·67	30·43	16·72
31·98	16·60	31·05	16·43

TABLE IV.

Electrical Conductivity.

"Bicop" Brand Copper		Tough-pitch Copper	
Hard % of Hard Stand	Bright Annealed % of Annealed Copper Std.	Hard	Commercially Bright Annealed
100·58	100·59	101·39	100·90
100·32	100·75	101·32	100·80
100·90	101·60	101·04	100·85
101·08	100·50	101·22	100·92

Some indication of the ductility of "Bicop" brand copper and tough-pitch copper is shown in Fig. 8. Both are wires, 0·081 in. diameter, which have been annealed in hydrogen at a temperature of 850° C. for a period of 30 min. No signs of fracture are shown on the "Bicop" sample. Twisting and tensile fracture tests carried out with a view to making comparisons between the two types of copper wire gave the results shown in Figs. 9 and 10, respectively. Twisting to destruction of a 0·1 in. square wire showed the superiority of "Bicop" wire, whilst in the tensile fracture it is noteworthy that the reduction of area amounted to approximately 80%, whereas 40% represented the reduction of area for the tough-pitch copper wire.

The difficulties encountered in controlling the atmosphere when melting copper are well known, the removal of oxygen and the development of a method of eliminating any oxygen pick-up during the time of pouring are other well-known problems, and it is a noteworthy achievement that, as a result of this investigation, these difficulties were overcome and production of a high-conductivity copper accomplished on a commercial scale. It will be appreciated that strict supervision is essential in all the various stages of production and the quality of this new brand copper is subjected to critical examination and tests to ensure uniformity.

Royal Charter for the Institution of Automobile Engineers

AT the annual meeting of the Institution of Automobile Engineers, held at the Royal Society of Arts early this month, Major-General S. C. Peck, C.B., D.S.O., the president, announced that His Majesty the King had recently been graciously pleased to grant the Institution a Royal Charter.

The Institution of Automobile Engineers was established in 1906, and it is a source of particular satisfaction to the membership that this recognition of the Institution's value as the professional body of the automobile industry has been made after so short a period of work as 32 years.

The annual report submitted at the meeting shows a steady increase in all branches of the Institution's activities—namely, technical literature and discussions, research, repair certificates, etc. During the year a building has been acquired as the new headquarters—i.e., No. 12, Hobart Place, Eaton Square, S.W. 1, which is eminently suited to its requirements and in keeping with the dignity of the Institution.

The Thermochemistry of Alloys

Direct determination of the heats-of-formation of the ternary alloys : Iron-Nickel-Aluminium, Iron-Cobalt-Aluminium, Copper-Nickel-Aluminium, Iron-Aluminium-Silicon, together with a series of alloys of the Copper-Manganese-Aluminium system.

This investigation* is an extension and continuation of previous work published in the *Mitteilungen aus dem Kaiser-Wilhelm-Institut fur Eisenforschung*, vol. 18 (1936), pages 109/130. There the methods are explained for directly determining the heats of transformation by allowing the molten metals to react in a specially adapted crucible arranged as a water calorimeter. The heats-of-formation of the ternary alloys Fe-Ni-Al, Fe-Co-Al, Cu-Ni-Al, Fe-Al-Si, in gaseous condition have been evaluated over the whole range of concentration, and the same is done for the ternary alloys of Cu-Mn-Al, which contains the ferromagnetic alloy Cu_2-Mn-Al. The method is checked for principal errors and it is found that the heat variations measured after the pouring together are due to the reactions of the metals to one another. The part of the reaction heat, which is due to the reaction of the baser metal to the oxides in the more precious metal, is sufficiently small, if care is taken for a thorough de-oxidation of the more precious metal. The repeated determination of the heats of formation of many alloys of the Fe-Al, Co-Al, Cu-Al, and Fe-Si systems showed good conformity with previous investigations ; and also the values of the heats of formation of the ternary alloys joined well to those of the binary alloys.

The results of the ternary alloys Fe-Ni-Al, Fe-Co-Al, Cu-Ni-Al, and Fe-Al-Si are shown in peculiar diagrams of the heats of formation, which gives a good survey of the conditions of energy of the ternary alloys. As far as possible the relations between heat-of-formation concentration-surfaces of the ternary alloys and their equilibrium are developed. In principle they are very similar in both binary and ternary systems. There are only few specific alloys whose heats of formation have a considerable influence on the character of the heat-of-formation surfaces. This relationship can be expressed as follows :—

The ternary alloys Fe-Ni-Al are influenced by the binary alloys Fe-Al, $Fe\text{-}Al_3$ and Ni-Al.

The ternary alloys Cu-Ni-Al by the binary alloys Cu_2-Al, Cu-Al, and Ni-Al.

The ternary alloys Fe-Al-Si by the binary alloys Fe-Al, $Fe\text{-}Al_3$ and Fe-Si.

The heats-of-formation of the ternary mixed crystals, contained in the investigated systems, are very important and with one exception (in the cobalt-corner of the system Fe-Co-Al) somewhat higher per gramme-atom of the metal solved in low concentration, than those of crystals, known for maximum values of their heats-of-formation.

The heat-of-formation surfaces turn openly towards the concentration planes only concave curvatures or acute and obtuse angles, not over-obtuse ones ; at least that is the case with all investigated systems, with the one exception of an edge in the system Fe-Co-Al.

Important is that the measured heat variations are marked correctly. Not the three metals as poured together for the tests, but alloys of two metals (for instance Fe-Ni, Fe-Co, Cu-Ni, Cu-Mn, Al-Si) which do not form recognised compounds, are cast to the third metal, which forms such compounds with each of the other metals. Therefore, the results of the tests are not actually the heats-of-formation of the ternary alloys, but, first of all, only the heat variations due to the addition of the third metal to the already formed alloy of the two first metals. If the heats-of-formation of the alloys of the first two metals are very small in comparison to the heat variations resulting from the addition of the third metal, the differences of these figures from the heat variations at the combination of the three metals are very small.

To find out the influence of the transformation of the binary alloys Fe-Ni, and Fe-Co on the heat-of-formation of the ternary alloys Fe-Ni-Al and Fe-Co-Al, curves showing the relation between the heat content and concentration of these binary alloys for various temperatures are investigated and compared with the two equilibrium diagrams.

Considerable divergencies have been found at these curves of the Fe-Co alloys. There are, obviously, in these alloys over the range of concentration 0 to 80% Co processes which go on during the γ-α transformation and also still in the α part below 800° C., and which produce considerable and additional quantities of heat. This heat production has its maximum value at about 50% Co, and is certainly connected with the divergencies of electric conductivity and magnetic saturation of the Ferro-Cobalt-Alloys.

The transformation processes in the low-aluminium mixed crystals of the occurring in the Fe-Ni-Al and Fe-Co-Al systems, especially the limits of the α state exercise a marked effect on the heat-of-formation surface.

The ferromagnetic alloy Cu_2-Mn-Al is shown at the curve of the heat-of-formation for the investigated ternary alloy Cu-Mn-Al by a sharp bend.

* Friedrich Körber, Willy Oelsen and Heinz Lichtenberg ; published by Kaiser-Wilhelm-Institut, Düsseldorf. Vol. 19, No. 11, price RM. 5·50.

The Oxidation of Wire and Its Influence on Subsequent Operations

After a general discussion on the oxidation processes occurring in steel during rolling, the authors* examine in detail the oxidation taking place during the manufacture of wire. Especially difficulties in pickling and drawing of wire, rolled in the usual manner at a continuous mill, and the subsequent operations of pickling, redrawing and coppering of water-hardened wire are discussed. The lay-out of a continuous wire rod mill plant and a semi-continuous wire rod mill plant are described. Two coils, one rolled at the continuous and the other at the semi-continuous mill, were investigated and it has been found that the wire coming from the continuous mill had, here and there, more scale and therefore needed longer pickling, connected with greater loss. Indeed, it was not possible to avoid great fluctuations of the figures found for these properties at the coil rolled by the continuous mill in the usual manner, which provides an element of uncertainty.

The influence of a cooling apparatus,beyond the finishing train of the continuous mill, on the oxidation and on the pickling properties of the wire is explained. It is possible to decrease the scaling and to improve the pickling properties of the wire by increasing the cooling effect and diminishing the temperature during reeling. The cooling section has been lengthened 13 ft., 21 ft., and finally, 30 ft., and the reeling temperature has been lowered to 650° C. from 700° C. These resulted in an equal and simultaneously very small oxidation along the whole length of the wire. And the effect on the loss by oxidation, starting of generation of hydrogen, and pickling time was very favourable. The reasons for the equal and unequal oxidation and behaviour during the pickling process, when applying different cooling sections, are discussed.

These results are confirmed by a large-scale investigation in a wire-drawing plant, where especially the easier drawing of the wire, the reduction of the loss by oxidation, and the saving of acid, brought about considerable economic advantage. In the case in question, where 9,000 ft. of wire have been produced per month, it is calculated at 0·976 Mark per ton.

Finally, investigations are described to find out the best manner of producing a water-hardened wire for upholstery springs by the continuous mill. The reasons for the difficulties in older processes are explained and it is shown how the difficulties of pickling, drawing and coppering could be avoided by using the new cooling section of 30 ft. length.

* Friedrich Körber and Werner Aebeck ; published by Kaiser-Wilhelm-Institut, Düsseldorf. Vol. 19, No. 12, price RM. 4.75.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Rearmament and Industry

THE improved industrial condition of this country, experienced during the last year or two, has developed mainly by improved trade resulting from improved world conditions and the Government measures to facilitate trade with this country have contributed. Such measures as the Ottawa Agreements and the Reciprocal Trade Agreements have succeeded in reducing certain trade barriers and opened the way for increased trade. This improvement in normal trade, which has naturally made greater demands on industry, has limited industry's margin available for armament production, and, although the Government's demands on industry to increase arm ament production have further improved conditions the pressure exerted may seriously react on production for home and overseas trade.

There must be very few in this country who do not realise the necessity for rearmament in view of the instability of world conditions, but on the completion of the programme now in progress there is a danger that industry may again experience a slump. To guard against this danger it is obviously necessary that normal industrial production should be disturbed as little as possible, and, in order to provide facilities for meeting the requirements of the armament programme, the whole industrial system should be thoroughly explored. It is probable that some sacrifice can be borne by the home trade, but every manufacturer contributing to the programme will consider seriously any sacrifice of the export of his products to overseas markets.

Building up a useful export trade during recent years has been extremely difficult: so many factors have interfered with legitimate trade that, with the improvement already made, it would be a calamity to check the progress. Yet the effect of the rearmament programme is already evident: several sections of the heavy industry, for instance, are so busily engaged on the programme that they are unable to deal with export requirements. Surely it would be wiser, and more economical in the long run, to import some of our armament requirements in order that interference with the export trade would be reduced to a minimum.

The demand for armaments is seriously affecting the shipbuilding industry. This, of course, is only one of the industries in which firms are asked to sacrifice their ordinary business connections and to give priority, whatever the cost, to Government work. It is well known that, before the War, by far the greater number of the world's merchant vessels, for British or foreign owners, were built in this country; to-day, however, foreign builders are not only constructing for their own nations but also for other foreign countries, and even for British owners. There are several reasons for this change with which the rearmament programme has no connection; shipbuilding in several other countries has been supported by the self-sufficiency movement, by Government subsidies, by special credit facilities not available to the same extent in this country, and by barter arrangements. In some instances frozen credits have led to ships for British owners being built abroad as the only means of reaching a settlement. But many British shipping companies have reduced, and in some instances suspended, their replacement programmes in consequence of the demands for steel for naval construction and the shortage of skilled labour in the shipbuilding industry. That the position is becoming serious in this industry will be appreciated when it is realised that thirty years ago the number of British-owned merchant vessels was greater than to-day's total by over a thousand vessels, whereas foreign-owned vessels have increased by over 3,000 in the same period. British shipping authorities put the shortage of British-owned modern vessels at 1,500, and to meet the requirements of trade, foreign-owned vessels are being employed in increasing numbers to carry British imports and exports.

It is noteworthy that some of the big railway groups are holding up their programmes of extensions and replacements until the steel stringency eases. The construction of many hundreds of bridges required for modern road and rail traffic is being held up for want of the necessary steel. While these potential demands for steel, so far as they are concerned with home requirements, will remain until the naval programme is finished, or is reduced to normal dimensions, the demand for steel for the manufacture of numerous products for export does not come into the same category. If this export trade is sacrificed it will take years of patient work to rebuild; certainly the shipbuilding industry will be hampered in its efforts to obtain orders from abroad.

The armament programme has and is making great demands upon the iron and steel industry, but additional supplies from abroad are necessary to assist the home consumption. Some indication of the strength of this consumption is shown by recent import and export figures. Some 308,700 tons of iron and steel were imported in January while only 194,700 tons were exported, a reversal of trade long experienced by the iron and steel industry in this country. The loss of this export trade is serious and very difficult to regain.

In some directions the industrial equipment of this country is unadapted for transfer to armament manufacture and in order to accelerate the pace to satisfy requirements new factories have been built or are in course of erection, while existing factories have been re-equipped. One of the equipment problems has been machine tools, and although there is still considerable delay in obtaining delivery, partly by the provision of increased production facilities in British works and partly by increased imports, this problem is not now quite so acute. It is probable, however, that greater use will be made of imports to facilitate the production of armaments, but even increased facilities have not enabled production to reach expectations, and in view of the industrial depression in the United States, there is little doubt that deliveries could be obtained from that country at shorter notice. Such a course would greatly improve relations with the United States and help the trade negotiations now in progress between the two countries. In addition, it would have the advantage of relieving our manufacturers to some extent to meet overseas requirements for their products.

To what extent such a course is possible is difficult to determine, but to concentrate a large part of industry on the production of armaments and to neglect profitable contracts abroad is bound to have repercussions. The main objection to the import of armaments to assist the programme is the effect it would have on the balance of trade payments, but obviously a substantial reduction of exports will have the same effect, with the added dis-

advantage of causing annoyance to customers abroad, probably leading to a severance of trade relations.

It is recognised that armaments are a grim necessity but the problem of supplying them should be considered calmly and a solution applied that will have relatively little effect on our export trade, which has been built up so laboriously during recent years. There is room for very careful planning of industry to take full advantage of the industrial margin available for armaments, to extend present factories or to build new ones, when they are considered essential, and to make greater use of armament imports from friendly nations to meet requirements in excess of the production facilities in this country.

Forthcoming Meetings

The Iron and Steel Institute and The Institute of Metals

The Joint Autumn Meeting will consist of a visit to the United States of America and Canada in September and October. The provisional programme for this very comprehensive visit covers the period from September 17 to October 29, on which latter date the party will arrive in New York in time to sail for Europe in the *Franconia* or the *Britannic*. The *Franconia* is due to arrive in Liverpool on November 7, and the *Britannic* in Southampton on the 6th.

Members are recommended to sail in R.M.S. *Empress of Britain*, leaving Southampton on September 17, and calling at Cherbourg, arriving at Quebec mid-day September 22; the afternoon of that day to be devoted to sightseeing and other entertainment. The following days will include visits to Montreal and Ottawa, visiting various places of technical interest or natural beauty on the way; thence to Toronto, Niagara Falls—with visits to the plants of the American Brass Co., the Bethlehem Steel Co., Canadian Westinghouse Co., Ontario Hydro Power Development, Pittsburgh Metallurgical Co., and the Union Carbide Research Laboratories—and on to New York for October 1.

During the visit to New York and the tour of the United States, members will be entertained by the American Iron and Steel Institute and the American Institute of Mining and Metallurgical Engineers.

Members travelling direct from Europe for the United States visit are recommended to sail in S.S. *Samaria* which leaves Liverpool on September 23 and arrives New York October 2.

In the afternoon of October 3, a joint meeting of both British Institutes with the American Iron and Steel Institute and the American Institute of Mining and Metallurgical Engineers will be held; the following day there will be technical sessions of the two British and the two American Institutes and visits to plants and laboratories. This section ends on the morning of Wednesday, October 5; the R.M.S. *Queen Mary* is due to sail from New York on that day.

Section III is a tour in U.S.A. which includes Cleveland, Detroit, Washington, Pittsburgh and other cities. The programme recommended for members of the Iron and Steel Institute comprises visits to New York and Baltimore and to some of the following: the Bureau of Standards, Bureau of Printing and Engraving, the Geophysical Laboratory and the Smithsonian Institute. Programmes recommended for those interested more in non-ferrous metals include visit to copper refineries, plants working brass, copper, lead and other non-ferrous metals.

The programme for the period at Pittsburgh has not yet been completed, but visits will be paid to various steel works, foundries, aluminium and electrical equipment undertakings. A very interesting tour is in prospect for those who go to Youngstown and Cleveland. The Detroit visit includes inspection of automobile factories—Ford, Chrysler and General Motors—strip steel, sheet steel, cold-drawn bars, springs, refrigerators, stampings, pre-fabricated structures, tyres, wheels and motor car body production. The fourth and concluding section contains alternative schedules and can extend to October 22, or by adopting one of the alternatives, with longer visits to Chicago, could terminate on October 25 or 29.

The Iron and Steel Institute

May 4, 5 and 6. Annual meeting and symposium on steelmaking, at the Institution of Civil Engineers. This will include a special report on "The Application of Time Study to Rolling Mills," by the Rolling Mill Committee of the Iron and Steel Industrial Research Council; and the "Fifth Report of the Corrosion Committee," by a joint committee of the Iron and Steel Institute and the British Iron and Steel Federation. The following papers will be offered at the May meeting: "Comparison of the Tensile Deformation Characteristics of Alloys at Elevated Temperatures," by C. R. Austin and H. D. Nickol; "An Experimental Enquiry into the Interactions of Gases and Ore in the Blast Furnace. Part V.—The Influences of Hydrogen and Steam at 450–850° C.," by W. A. Bone, F.R.S., H. L. Saunders, and H. J. Tress; "Influence of Composition and Treatment on the Rate of Acid Attack on Mild Steel," by C. A. Edwards, F.R.S., D. Luther Phillips, and D. F. G. Thomas; "The Effect of Copper on Some Alloy Steels," by R. Harrison; "Martensitic Grains in Rapidly-Cooled Ingot Iron and Mild Steel," by B. Jones and N. Gray; "The Effect of Chromium and Carbon Contents on the Co-efficients of Thermal Expansion of Chromium Steels," by J. A. Jones and W. C. Heselwood; "Solidification in Open-Topped and Closed-Topped Ingot Moulds," by B. Matuschka; "The Exact Quantitative Estimation of Ferric Oxide and Sulphide Sulphur in Basic Slags," by E. Maurer and F. Haderer; and, "The Atmospheric Corrosion of Galvanised Iron Wire and its Bearing on Specification Testing," by C. E. Richards.

The Institute of Metals

May 4, at 8 p.m. The 28th Annual May Lecture of the Institute of Metals will be delivered by Prof. G. I. Taylor, F.R.S., on "Plastic Strain in Metals," in the Hall of the Institution of Mechanical Engineers, Westminster. Tickets can be obtained from Mr. G. Shaw Scott, 36, Victoria Street, London, S.W.1.

The Institution of Mechanical Engineers

April 22. General meeting at 6 p.m. "Some Problems in the Transmission of Power by Fluid Couplings," by Harold Sinclair, M.I.Mech.E.; April 25, at 6-45 p.m. Graduates' Section, "Modern Steelworks Plant," by G. E. Robinson, G.I.Mech.E.; April 29, at 6 p.m., Steam Group, informal discussion on "How to use Steam Efficiently for Power and Process," to be introduced by John E. Belliss, A.I.Mech.E.; and May 6, at 6-30 p.m., Informal Meeting with exhibition of industrial cinematograph films. All at Storey's Gate, St. James's Park, London.

The Royal Aeronautical Society

The lecture arranged for April 26, on "Factors Controlling the Development of Electrical Ignition on Aero Engines," by Dr. G. E. Bairsto, was postponed and will be given next Session.

On April 21, Prof. John E. Younger will give an illustrated lecture on "High Altitude Flying" in the Lecture Hall of the Institution of Mechanical Engineers, Westminster, at 6-30 p.m.

Sunday, May 8, the R.A.S. will hold its Annual Garden Party at the Great West Aerodrome near Hayes, Middlesex. It is timed to begin at 2-30 p.m.; tickets are 5s. and applications after May 5 may have to be refused.

The Soviet Government has placed with the Davy and United Engineering Co., Ltd., Sheffield, a big order for the construction of steelworks plant and machinery. In addition to a large forging press, the order comprises a hydraulic plate-bending press with mechanical handling equipment, and a 4-high reversing mill for cold-rolling steel strip.

Strength Properties of Rolled Mild Steel Sections

By G. WELTER and M. S. WOLAGIEWICZ

In acceptance tests on structural steel, regard should be given to changes in mechanical properties, which may be appreciable according to the position of the test pieces in the rolled sections. Tests on girders are discussed which give useful information in connection with the use of these structural shapes and on the need for greater care in the casting and rolling operations.

IN order to judge the quality of structural steels it is essential to be acquainted with their properties. It is an inherent feature in the manufacture of a joist, for instance, made of a steel ingot weighing several tons, that strength properties vary according to the position from which the test piece is taken, e.g., at the top or bottom of the ingot, which will possibly show wide ranges of variation. It is important also whether the test pieces are cut from the flanges of a joist or crosswise, or its web, and whether in the direction of rolling, because variations in the material due to rolling operations are likely to occur which impair the quality of the product.

To secure a comprehensive impression of these viewpoints in connection with rolled girders, tests have been carried out on rolled sections. Standard profiles Nos. 40 and 28 were employed for these tests, and their mechanical properties in flange and web were investigated, both in the direction of rolling and transversally. In addition to these features, the influence of the position of the test pieces with respect to the top or bottom end of the ingot was investigated in connection with section No. 24, the ingot from which the joist was rolled having a weight of 3½ tons. Particular attention was given to the following characteristics: breaking strength Rr in kg/sq. mm., elongation A in %, reduction of area C in %, notched bar toughness U in kg. m/sq. cm., hardness HB in kg/sq. mm., as also the chemical composition micro and macro texture, the non-metallic impurities[1] (for standard section No. 24) and the position of the notch toughness. Similar tests were carried out by Ros on Differdinger-Grey girders[2]. All the tests pieces had a diameter of 5 mm.; the impact test pieces after Mesnager were of standard proportions (F = 0·8 sq. cm.).

Test Results

(*a*) *I-Joists No.* 40. The test results reproduced in Fig 1 are for rolled section No. 40; the dash line giving results in rolling direction for flange and web, while the bold line refers to results obtained crosswise to rolling direction. The strength properties of the flange of this section vary within comparatively close limits. The tensile strengths Rr (Fig. 1a) lie between 35 and 39 kg/sq. mm., while the values for the tests transverse to the rolling direction (bold line) are somewhat higher (37 to 39 kg/sq. mm.). Correspondingly, the values for the elongation A% (Table I) also are fairly uniform and lie between 30·9 and 40%. Somewhat more variable are the values for the reduction of area C% (Fig. 1) which move in the rolling direction between 71 and 78%, while for the tests crosswise to rolling direction they are lower and embrace the limits 54 and 67%. Against this notch test values U in kg × m/sq. cm. (Fig. 1d) are remarkably low and only amount to 0·5–6·2 kg. m/sq. cm. The hardness HB in kg./sq. mm. of the upper and lower flange (Fig. 1b and i) are approximately equal and move between 105 and 118 kg./sq. mm.

Somewhat different are the mechanical values of the web, which is comparatively thin with respect to the flanges and presents a large surface. The tensile strengths move within exceedingly close limits and vary only by about 2 kg./sq. mm. although they lie appreciably higher than those for the flanges. All the test pieces taken from the web show resistance values between 43 and 45 kg./sq. mm. which drops to about 36 kg./sq. mm. at the points where it passes over into the flanges. No appreciable influence of the direction of rolling upon the breaking strength is apparent in these tests (bold outline, Fig. 1e).

Table 1

TEST NUMBER	A%
1	32·2
2	31·2
3	32·7
4	33·5
5	31·7
6	30·9
7	31·4
8	34·0
9	34·4
33	31·0
34	39·5
35	40·0
36	35·8
37	33·0
38	33·0
39	37·3

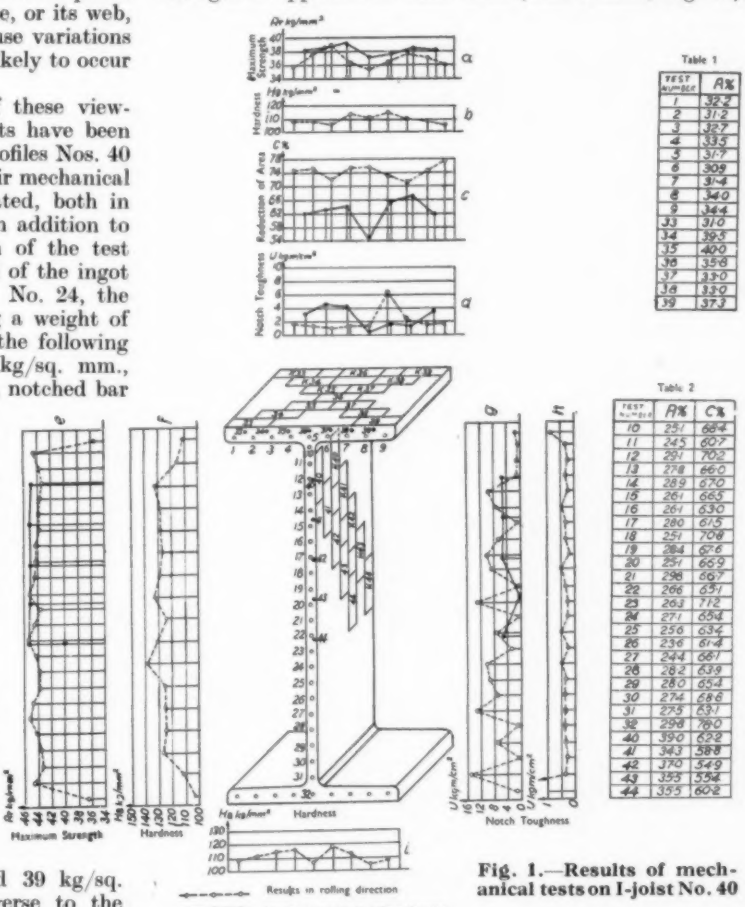


Table 2

TEST NUMBER	A%	C%
10	23·1	68·4
11	24·5	60·7
12	29·1	70·2
13	27·8	66·0
14	28·9	67·0
15	26·1	66·5
16	26·1	63·0
17	28·0	61·5
18	25·1	70·8
19	28·4	67·6
20	25·1	66·9
21	29·8	66·7
22	26·6	65·1
23	26·3	71·2
24	27·1	65·4
25	25·6	63·4
26	23·6	61·4
27	24·4	66·1
28	28·2	63·9
29	28·0	65·4
30	27·4	68·6
31	27·5	63·1
32	29·8	76·0
40	39·0	62·2
41	34·3	58·8
42	37·0	54·9
43	35·3	55·4
44	35·5	60·2

Fig. 1.—Results of mechanical tests on I-joist No. 40

Also the elongation values for the web are lower (23·6%–29·8%, Table 2) than those of the flange and this permits of inferring that the web of the joist was rolled at temperatures of less than 600° C. With a rolling temperature of 600° C. and a reduce pass of 10%, tensile values of approximately 44 kg./sq. mm. are reached as against 35–36 kg./sq. mm. at higher temperature.[3] Correspondingly, the hardness (Fig. 1f) in the web also is higher by 10 to 15 Brinell units than in the flanges. The exceedingly low notch toughness also should find an explanation in a critical rolling temperature at critical reduction passes (500° C. and 10% rolling degree cf. *Pomp, Stahl Und Eisen* 1920, p. 1,261) and this property moreover varies in the web to very appreciable extent. Thus, for example, impact test values of 0·4 kg. m./sq. cm. and 14·5 kg. m./sq. cm. were recorded from adjacent test pieces (tests Nos. 30 and 31, Fig. 1g). Figs. 2

1 J. Czochralski, Wiad. Inst. Met. 2, 1935, p. 34.
2 M. Ros "The Wide-flanged Differdinger-Grey Girders," report No. 52, Federal Test Laboratory for Materials of the E.T.H. Zurich, 1930.
3 Wust and Huntington, *Stahl und Eisen*, 1917, p. 832.

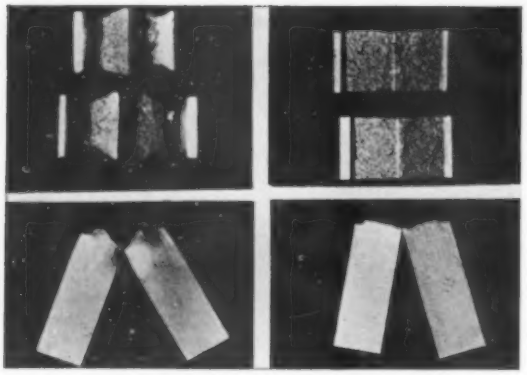


Fig. 2. **Fig. 3.**
Notched bar tests, after Mesnager, from the web of the I-joist No. 40, with medium and low notch toughness (⅓ actual size)

and 3 show the breaks and the zones of deformation of these two tests. Contrary to expectations, thermal treatment (annealing at 700–750° C.) of the samples, taken in the rolling direction, from the web brought no improvement, but, if anything, the notch toughness values were reduced ; the latter were uniform after treatment, but only amounted to 0·5 kg. m./sq. cm. and less throughout the web (Fig. 1h). The material was presumably influenced deleteriously by the rolling process at unsuitable temperatures and reduction passes, notwithstanding adequate static breaking strength values, to such extent that the notched impact values were exceedingly low and that they could not be improved even by thermal treatment (annealing at 700–750° C. for 3 hours).

As the position of the notch relatively to the rolling direction might affect the results, additional tests were carried out on samples from this girder, with notches parallel and perpendicular to the rolling direction (Fig. 4).

TABLE I.
NOTCH PERPENDICULAR TO THE DIRECTION OF ROLLING.

Mark	Work P.kgm.	Notch toughness U.kg. m./sq. cm.
K1	0·40	0·50
K2	0·46	0·58
K3	0·59	0·74
K4	0·53	0·66
K5	0·53	0·66
	Mean U 0·60	

TABLE Ia.
NOTCH PARALLEL TO THE DIRECTION OF ROLLING.

Mark	Work P.kgm.	Notch toughness U.kg. m./sq. cm.
K6	3·98	4·98
K7	1·07	1·34
K8	0·79	0·99
K9	1·68	2·11
K10	0·34	0·42
	Mean U 1·97	

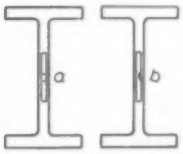


Fig. 4.—Position of the notch of additional samples tested

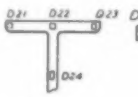


Fig. 5.—Positions from which samples were taken for chemical analysis

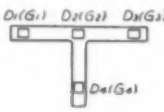


Fig. 7.

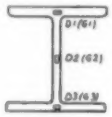


Fig. 7a.

Positions from which samples were taken

It is evident from Tables I and Ia that there is ratio of 1 : 3 in favour of those test pieces whose notches were in the direction of rolling. The manner, *inter alia*, in which the notch lies in these tests relative to the rolling texture and to the fibre texture has a decisive influence upon the results. Accordingly it is important how the notch is situated in the impact tests, particularly with regard to the direction in which the material was rolled. Results may be obtained, as these experiments show, which are three times higher, as in this case, with respect to comparative tests with the same material, and this simply by the particular choice of notch position relatively to the rolling direction.

(*b*) *I-Joists No.* 28. Chemical analysis carried out on this joist in various places of the section as per Fig. 5 (sides and centre of top flange, centre of web) and Table II show the known phenomenon that sulphur and phosphorus content is higher in web centre and at the point of transition between web and flange (flange centre) than at the sides of the flange. Similarly, the carbon content is higher in these places while manganese does not show any appreciable variations. Accordingly, the impression taken of these joists by the Baumann method show clearly an enhanced sulphur content. A few random tests to determine the non-metallic impurities in these girders indicated that the material is comparatively pure and that the existent impurities keep to the usual limits in proportions and quantity.

TABLE II.

Mark	%C	%Mn	%Si	%P	%S
D21	0·15	0·54	0·0030	0·029	0·024
D22	0·19	0·57	0·0025	0·036	0·031
D23	0·15	0·56	0·0030	0·031	0·020
D24	0·22	0·56	0·0025	0·046	0·044

In Fig. 6 are reproduced the results of the mechanical tests of these girders by means of samples taken parallel

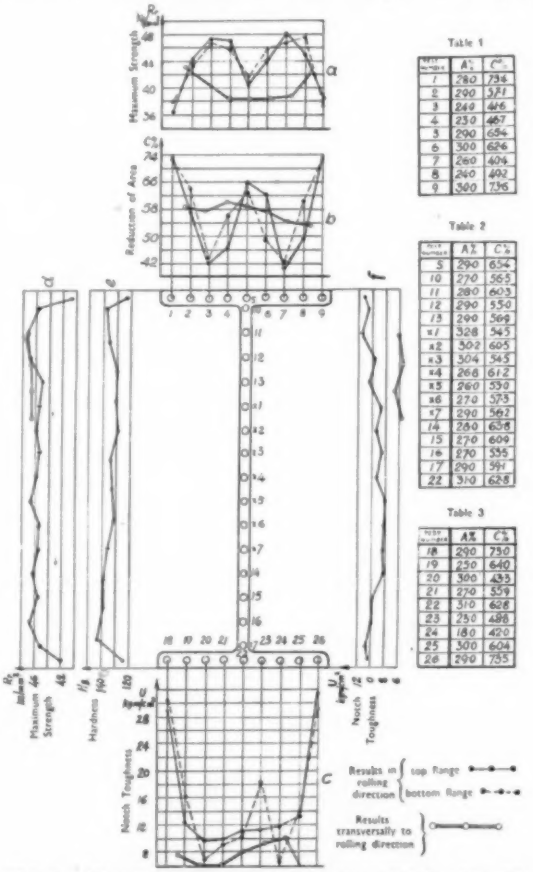


Table 1

Notch Number	A%	C%
1	280	736
2	290	521
3	240	416
4	250	467
5	290	654
6	300	626
7	260	604
8	240	402
9	300	736

Table 2

Notch Number	A%	C%
5	290	654
10	270	565
11	280	603
12	290	550
13	290	569
x1	328	545
x2	302	605
x3	304	545
x4	268	612
x5	260	530
x6	270	573
x7	290	562
14	280	658
15	270	609
16	270	535
17	290	591
22	310	628

Table 3

Notch Number	A%	C%
18	290	750
19	250	640
20	300	433
21	270	559
22	310	628
23	250	498
24	180	420
25	300	604
26	290	735

Fig. 6.—Results of mechanical tests on I-joist No. 28

to the direction of rolling. The deviations between the individual tests are very high with this joist, more especially in the top and bottom flange, bold and dash line, in Fig. 6a, and run approximately parallel to one another. The breaking strength shows values fluctuating between 36 and 48 kg./sq. mm., the lowest values being on the sides of the flange. In the centre of the flange a value of 40–42 kg./sq. mm. was ascertained. Accordingly, the reduction of area takes an inverse course, and this applies to a certain extent equally to the elongation (Fig. 6b and Table I). The notch toughness of the flange, which on the whole, is appreciably higher than with the previously tested girder No. 40, decreases from the sides, where it is over 28 kg./sq. cm., heavily towards the middle ; here the values lie between about 7–12 kg./sq. cm. (with the exception of point 23, Fig. 6c).

Test pieces taken transversally to the rolling direction (double line, Fig. 6) display a somewhat varied relation in point of breaking strain, reduction of area and notch toughness compared with the tests in rolling direction (Figs. 6a to e). Tensile strength and notch toughness are lower throughout.

As against this the values both in rolling direction and also crosswise, in the web of this girder are fairly uniform for strength, hardness and notch toughness (Figs. 6d-f), and are between 41 and 48 kg./sq. mm. for the breaking strain, between 125 and 140 kg./sq. mm. for the hardness and between 8 and 11 kg.m./sq. cm. for the impact toughness in rolling direction while transversally the latter

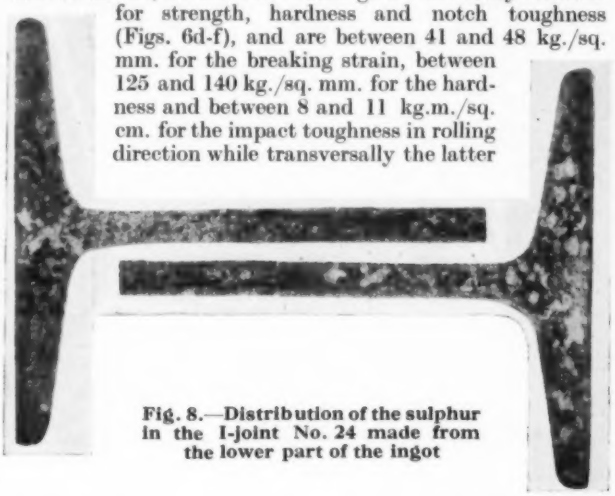


Fig. 8.—Distribution of the sulphur in the I-joint No. 24 made from the lower part of the ingot

shows about 5·5 to 6·5 kg. m./sq. cm. (double line, Fig. 6f).

(c) *I-Joist No.* 24. These girders were tested somewhat more thoroughly, inasmuch as in addition to the mechanical properties longitudinally and across the rolling direction, it was also desired to examine the influence of the initial rolling of the ingot, also the chemical composition and the number and distribution of the impurities in the rolled girder section, upon the further mechanical features. These girders were made from an ingot of 3·5 tons which was rolled down after having removed the crop-end (13 to 15%).

After completion in the finishing pass sections were taken from these girders, one corresponding to the top of the ingot (*G*) and one from the bottom (*D*), each of approximately 1 metre in length and tested after cutting out the particular test pieces.

The Baumann prints, particulars of which are given in Tables III and IV, clearly show the difference in sulphur content between the girder ends corresponding to the top and bottom ends of the ingot. In both cases the flange

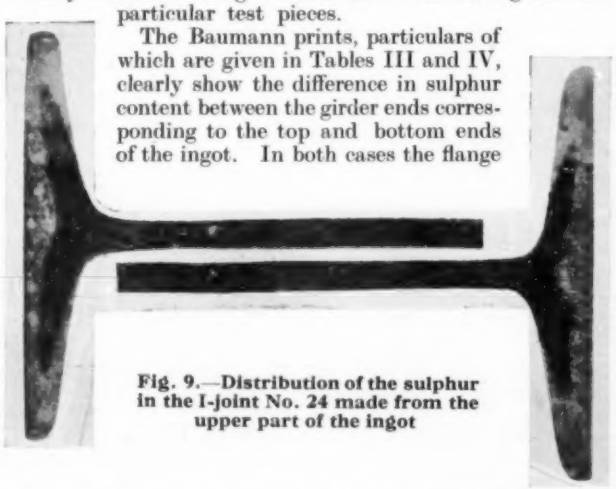


Fig. 9.—Distribution of the sulphur in the I-joint No. 24 made from the upper part of the ingot

sides of each section contain about the same amount of sulphur. This is also evident from the chemical analysis carried out according to Table III.

The places whence the samples were collected are shown in Fig. 7. Higher values for carbon, phosphorus and sulphur were found in the web tests D4 and G4 than in the flange. This is particularly obvious with the girder G which originates from the top of the ingot. Values for carbon and phosphorus in the web come to approximately twice the amount of the lowest figures in the flange and

TABLE III.

Mark	%C	%Mn	%Si	%P	%S
D1	0·090	0·45	less	0·023	0·019
D2	0·093	0·45	than	0·020	0·021
D3	0·090	0·46	0·01	0·023	0·020
D4	0·095	0·45		0·026	0·025
G1	0·083	0·44	less	0·023	0·019
G2	0·097	0·45	than	0·035	0·026
G3	0·090	0·44	0·01	0·024	0·020
G4	0·170	0·50		0·049	0·067

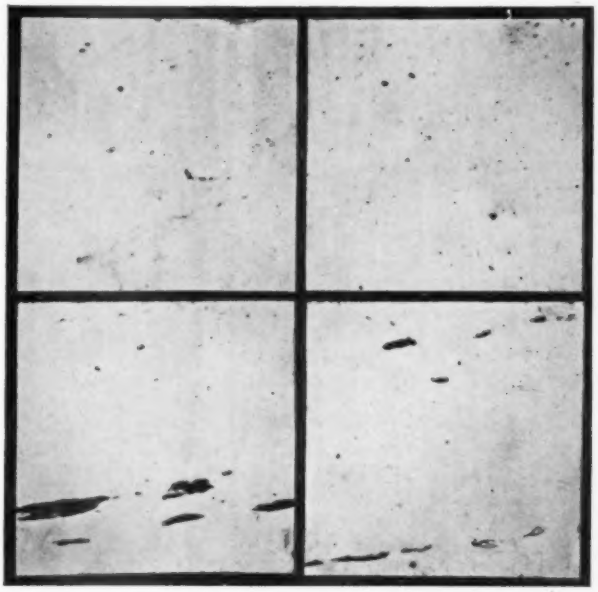


Fig. 8a.—Distribution of non-metallic inclusions (after Czochralski) in the I-ingot No. 24 made from the lower part of the ingot. Top row, crosswise to rolling direction. Bottom row, longitudinally to rolling direction. × 100

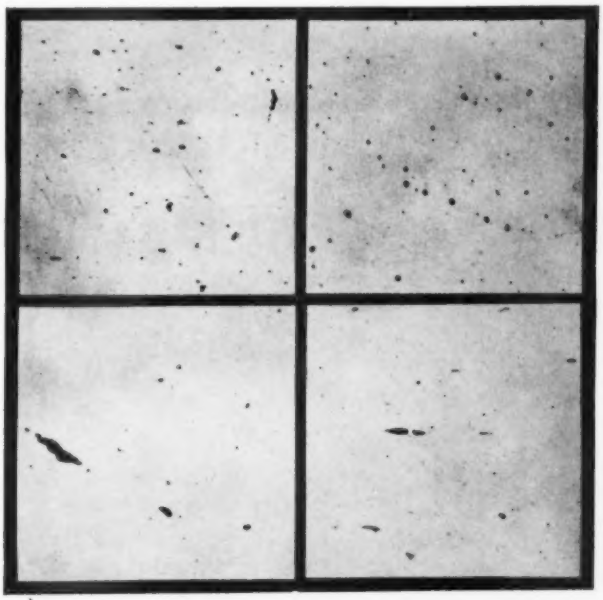


Fig. 9a.—Distribution of non-metallic inclusions in the I-joist No. 24 made from the upper part of the ingot. Top row, crosswise to rolling direction. Bottom row, longitudinally to rolling direction

in the case of sulphur even three times as high. These variations in the composition of the various zones of these girders have an influence upon their mechanical properties, which show appreciable differences. In order to ascertain whether, apart from chemical composition, there might be

noticeable disparities with regard to the non-metallic impurities between the girder sections from the top and bottom of the ingot, the impurities in these joists were determined by the method of Czochralski, quantitatively and with regard to sizes. To this end test pieces were taken in accordance with Fig. 7a from the upper, central and lower portion of the webs of both girder sections which were prepared both parallel and crosswise to the direction of rolling, and the non-metallic impurities determined under a microscope of 100-fold magnifying power in field of view of 75 × 75 mm. Both the mean values as

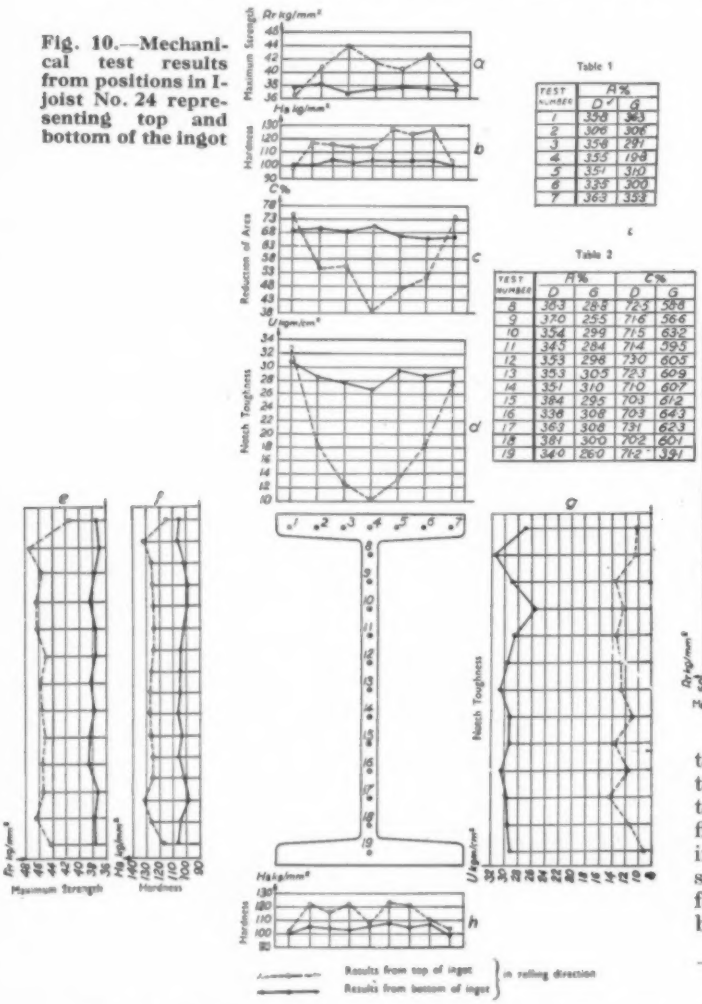


Fig. 10.—Mechanical test results from positions in I-joist No. 24 representing top and bottom of the ingot

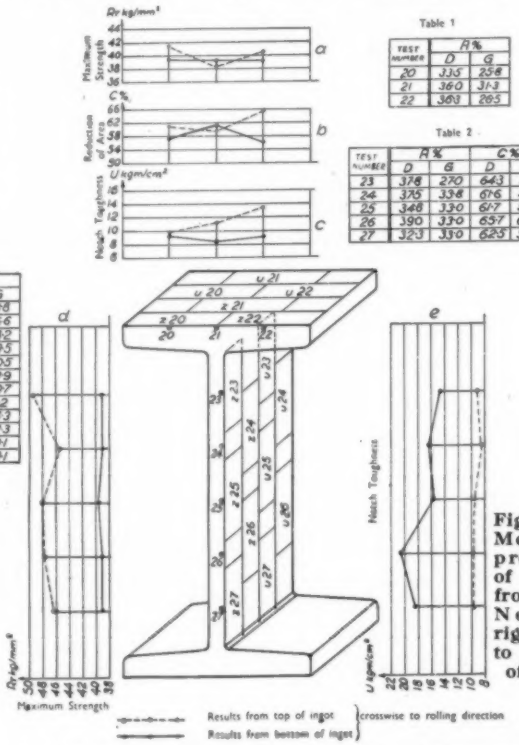


Fig. 11.—Mechanical properties of samples from I-joist No. 24 at right angles to direction of rolling

also the maximum values from three layers, each about 1 m.m below the other, and the total mean values were calculated therefrom, and, in addition, the shape of the impurities (granular, streaked or banded structure). The values obtained in this way have been compiled in Table IV, which shows that there was no fundamental difference with respect to non-metallic impurities between the top, centre and bottom portion of the web, viz., both in specimens from the top and bottom ends of the ingot in longitudinal and transverse tests. Some samples in the ingot top corresponding to the upper and lower portion of the web appeared quantitatively to have more impurities (G1 and G3, Table IV). Fig. 8 corresponds to the specimen D2 and Fig. 9 to the specimen G2. Generally speaking, however, the material of these girders with regard to non-metallic impurities must be considered fairly pure and these cannot therefore exert any decisive influence upon the mechanical properties.

The mechanical test results for the girder portions corresponding to the top of the ingot (G, dash line) and the bottom (D, bold line) for the tests in rolling direction are reproduced in Fig. 10. It will be gathered from the illustrations a to h that all the mechanical values of the girder originating from the ingot bottom D are particularly homogeneous and do not show an erratic result. Fluctuations that do occur lie within very close limits. Both the flange and the web, the breaking strains Rr (Fig. 10a), the hardnesses HB in kg./sq. mm. (Figs. 10b and h), and also the elongations, Table 1, are lower than the values of the girder G, from the top of the ingot, while the notch toughness U (Fig. 10d and g) and web are on the average appreciably higher than applies to the corresponding values of the girders made from the top. The differences between those from the top of the ingot G and the bottom D amount to approximately 6–7 kg./sq. mm. for the strength in the flange (Fig. 10a) and in the web to about 8–9 kg./sq. mm. in favour of the girders from the top of the ingot which shows the higher values. In contradistinction the girder from the ingot top is more brittle in flange and web, as may be deduced from the lower elongation (Fig. 10, Tables 1

TABLE IV.

Mark	Layer	Longitudinal Test		Transverse Test		Shape of Impurity
		Impurities				
		Slide Centre	Maximum	Slide centre	maximum	
D1	1	1/2/Jc	11/6/160Jc	4/6Jc	9/10Jc	Granular and streaks
	2	2/4/10	5/3/14	2/4	3/4	
	3	3/2/36	4/2/8	3/4	5/8	
	mean	2/3/6	6/4/63	3/5	6/7	
D2	1	2/2/2	7/3/11	8/10	4/11	Granular and streaks
	2	3/2/6	4/3/6	4/6	5/8	
	3	2/3/8	3/3/10	2/3	6/8	
	mean	2/2/5	5/2/9	5/6	5/9	
D3	1	2/2/2	3/2/4	3/3	4/6	Granular and streaks
	2	3/3/5	10/5/49	4/6	7/8	
	3	3/3/6	4/4/6	6/6	7/8	
	mean	3/2/4	6/4/20	4/5	6/7	
G1	1	1/4/8	2/2/8	10/12	18/22	Banded structure and streaks
	2	1/3/5	2/3/7	11/13	13/16	
	3	1/2/1	3/6/30	8/9	10/12	
	mean	1/3/5	2/4/15	10/11	14/17	
G2	1	2/2/3	4/2/16	4/6	5/8	Granular
	2	1/2/2	2/2/3	3/4	4/6	
	3	3/2/5	4/3/12	3/6	5/11	
	mean	2/2/3	3/2/10	3/5	5/8	
G3	1	3/2/5	4/2/6	12/14	14/16	Banded structure and granular
	2	2/2/3	9/3/24	19/22	31/33	
	3	1/3/2	2/2/3	16/20	21/24	
	mean	2/2/3	5/3/11	16/19	22/24	

and 2) and reduction of area figures, (Fig. 10c and Table 2), more especially the notched bar values, which at the weakest point in the flange and web amount to about 1 : 2·5 or 1 : 3 (Fig. 10d and g). Apart from this the variations of most of the values of the tests corresponding to the top end of the ingot are appreciable.

The strength values for the two girders G and D across the rolling direction are produced in Fig. 11. The differences in the flange are here considerably smaller than in the foregoing case, while those of the web show corresponding differences.

(*d*) *Comparison of Test Results.* In Figs. 12 to 17, are reproduced the test results for the three different girders.

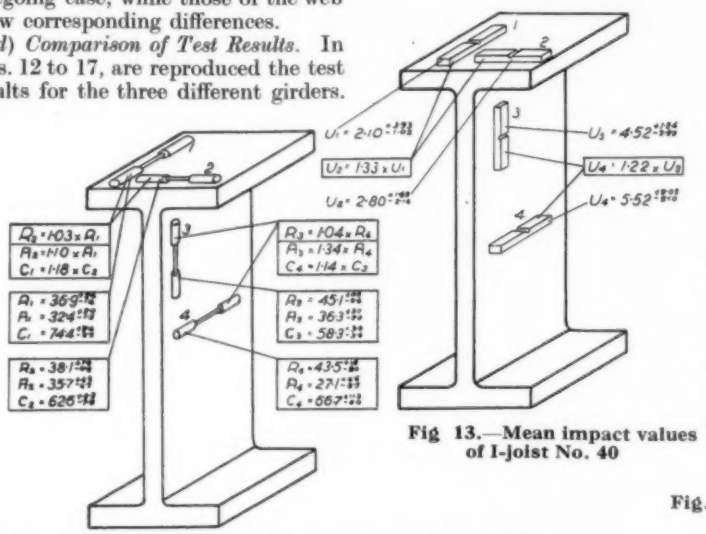


Fig. 13.—Mean impact values of I-joist No. 40

Fig. 12.—Mechanical properties of specimens from I-joist No. 40.

In addition to the mean values of various tests which have been entered, together with the deviations from these values, the results of the mean values from tests longitudinally to the rolling direction have been placed in juxtaposition to those secured crosswise to the rolling direction, both for the flange and for the web of the particular joists. It will be evident from Fig. 12 reproducing the breaking strain, elongation and reduction of area of the girder No. 40 that these mean values (with the exception of reduction of area) are higher transverse to the rolling direction than longitudinally. This applies both to the flange and also the web. The greatest difference is shown by the elongation A3, which is about 1·34 times the figure in the rolling direction. The greatest discrepancies from the

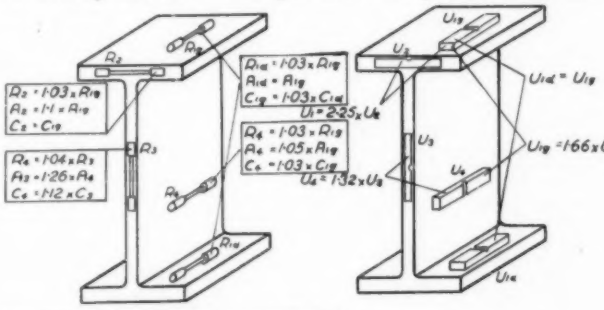


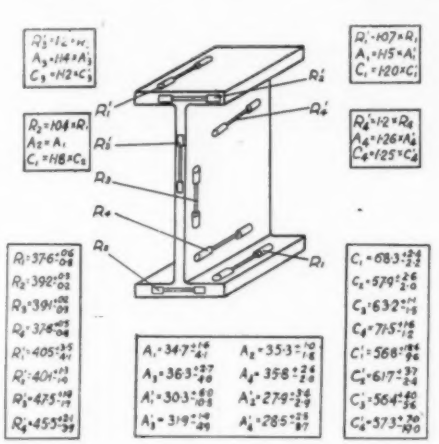
Fig. 14.—Mechanical properties of specimens from I-joist No. 28

Fig. 15.—Mean impact values of I-joist No. 28

mean values are the resistance R^1 (+ 1·9—8 kg./sq. mm.), the elongation A2, (+ 4·3–4·7%), and the reduction of area C^1 (+ 11·3—6%).

In a similar manner the mean values for the notch toughness are reproduced in Fig. 13. A feature of interest here is that the tests from the flange crosswise to rolling gave only about 33% higher values than those in the direction of rolling, whereas with the web the longitudina tests showed the highest values (U4 = 1·22 × U3) The greatest deviations from the average value, which was very low throughout, were +9·03 and −5·10 m. kg./sq. cm. The mean values of the remaining girders No. 28 and 24 are compiled in a similar manner in the Figs. 14 to 17.

(*e*) *Test Results.* It is manifest from the test results that, according to the position of the specimens in the rolled product, appreciable differences in properties are

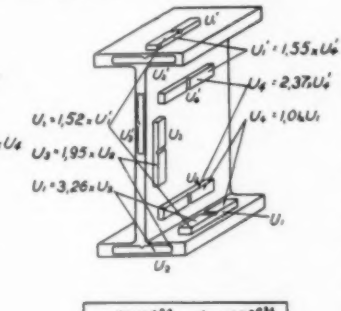


R^1 = ingot top R = ingot bottom

Fig. 16.—Mechanical properties of specimens from I-joist No. 24

to be recorded, more especially in mechanical strength characteristics. Not only were values determined between tests in the direction of rolling the girders, or crosswise thereto, which showed entirely different behaviour in tensile and notched bar tests, but frequently appreciable differences were ascertained between the flange and web of the same joist, particularly in impact toughness. Furthermore, fundamental differences were found between the properties of girders made from the top and bottom ends of the ingot. The differences in the material observed, in some instances quite appreciable, should be interconnected not only with the deviations in chemical composition or non-metallic impurities in the materials, but mainly with various degrees of rolling and critical rolling temperature in the course of manufacture. These tend to be entirely different, for example, in the comparatively thick flanges and thin webs of I-joists during the rolling operations.

Generally speaking, it may be said that it is the unavoidable imperfections which occur in steelmaking, both while producing the ingots and in rolling operations on the material, that influence the chemical composition, especially the resistance to impact loads. In acceptance tests, regard should be given to these changes in mechanical properties, which may amount to an appreciable figure according to the kind and position of the test pieces in the rolled girder. To the consumer also tests on these lines may give useful information in connection with the employment of these structural materials, while the producer may be induced to give attention to higher quality products by exercising greater care in the casting and rolling operations.



U^1 = ingot top U = ingot bottom

Fig. 17.—Mean impact values of I-joist No. 24

Strength of Nickel-Chromium Alloys at High Temperatures

ALLOYS used for electrical resistance wires are sometimes used in wrought form for the fabrication of load-carrying parts for high-temperature service. While creep tests are necessary for the evaluation of their long-time load-carrying ability, the ability to survive a sudden overload is also important, and this may be approximately determined by short-time high-temperature tests, such as have been carried out by K. E. Quier,[1] who has determined the high temperature strengths of the 80% nickel, 20% copper alloy up to 980° C., and of the 60% nickel, 16% chromium, 24% iron alloy up to 870° C., in a series of short-time tests.

The tests were carried out, using the testing equipment and procedure conforming to the Standards of the American Society for Testing Materials, on ¼ in. diameter rod, machined to 0·167 in. and having a gauge length of 0·75 in. The furnace used was gap wound and showed a temperature distribution over the gauge length within 1° C. up to 870° C., and within 3° C. at 870° C. and over. Test specimens were brought to the desired temperature and held there for 20 min. before starting the test, and the motion of the head of the testing machine was 0·05 in. per minute. Tests were made at 22° C. and over the range 150° to 980° C. Neither the yield point nor the limit of proportionality was determined. Two to four tests were made on the 80/20 alloy at each temperature and the results obtained for tensile strength as well as those for elongation and reduction of area agreeed closely up to 760° C. At 760° C. and 870° C. the ductility values on duplicate tests showed wide divergence, but agreed well again at 980° C. Only one specimen of the 65/16/24 alloy was tested at each temperature.

The 80/20 alloy, with a tensile strength of approximately 50 tons per sq. in., at 22° C., showed only a slight falling-off in strength up to 480° C., after which the strength diminished rapidly to less than 0·25 tons per sq. in. at 980° C. The temperature-stress curve of the 60/16/24 alloy was of a similar nature, except that it had a higher initial strength of over 62 tons per sq. in., which fell to 58 tons per sq. in. at 480° C. The 80/20 alloy also showed a deep dip in the ductility curve at from 480° to 700° C., with a minimum at 600° C., but recovered sharply at 700° C., after which the ductility falls off again. Its fracture was inter-crystalline up to 650°, but inter-crystalline from 650° to 980° C., and some grain growth was noted at 870° C., but was very pronounced at 980° C. The brittle range noted in the 80/20 alloy was not so marked in the higher iron alloy, but some inter-crystalline cracking was also observed in the fractures of the latter at 750° and 870° C.

When the results obtained by Quier are compared with the results obtained by Pilling and Worthington[2] for two alloys of the 80/20 type and one alloy of the 60/16/24 type, certain differences are observed. The first of the latter investigator's 80/20 alloys, which contained 2·3% manganese, showed a dip in the ductility curve between 540° and 650°, but did not fall again, while the second 80/20 alloy, with little or no manganese, did not fall off in ductility so soon, fell to about the same level as the first alloy at a higher temperature, and did not rise appreciably thereafter. Quier's curves for the 80/20 alloy, which contained about 1% manganese, are almost the resultant of these two, and although this evidence is probably insufficient to prove any correllation between the manganese content and the ductility of the 80/20 alloy in this "brittle range," it does show that rather small changes in composition or in melting practice can profoundly affect the ductility of this type of material.

Pilling and Worthington's data for an alloy of the 60/16/24 type show such an alloy to be weaker and more ductile at ordinary temperature when compared with the results obtained by Quier. Between 700° and 870° C., however, the strength of the two alloys is of the same order, while the elongation and reduction of area values agree fairly well within the range. The change in the relative tensile strength of the 80/20 and 60/16/24 alloys at various temperatures is also worthy of note. Pilling and Worthington found the 80/20 alloy to be of superior strength at all temperatures, whilst Quier found the 80/20 to be weaker than the 60/16/24 alloy below 620° C. and stronger and increasingly so in comparison as the temperature rose above this value. These differences between the two results may result from the fact that alloys of these types are extremely sensitive to the rate of loading and the different rates used by the different investigators may have altered the results materially.

1 *Metals and Alloys*, 1938, Vol. 9, No. 2, pages 40 to 44.
2 A.S.T.M.—A.S.M.E. "Joint Symposium on Effect of Temperature on the Properties of Metals, 1931, page 502."

Two New British Chemical Standards, Carbon Steels "D" and "F"

The Bureau of Analysed Samples announces two new standards steels which are now ready for issue :—

	Free-cutting Carbon Steel "D." %	Carbon Steel "F." %
Carbon	0·114	0·525
Silicon	0·007	0·109
Sulphur ?	0·237	0·032
Phosphorus	0·082	0·050
Manganese	0·810	1·010

Steel "D" is a typical modern high sulphur and phosphorus free-cutting steel and is of particular interest in connection with the determination of the high sulphur content, and the low carbon, by combustion, in the presence of high sulphur.

Steel "F" is a typical 0·5% basic open-hearth carbon steel, but with phosphorus and manganese near to the top limit which is frequently specified. It has, therefore, appreciably higher phosphorus and manganese than steel "J."

As usual, each standard has been analysed by a number of chemists experienced in the analysis of that particular class of steel and the list includes independent chemists, also chemists representing well-known users and manufacturers. The standards are issued in bottles containing 25 grms., 50 grms., 100 grms. and 500 grms. Each bottle is provided with a certificate showing the analysis of each chemist, together with a reference to any feature of interest in connection with the determination of each element.

The standards may be obtained from Headquarters, 3, Wilson Street, Middlesbrough, or through any of the usual chemical dealers.

Canada's Nickel Output in 1937

NICKEL production in Canada in 1937 was the greatest ever recorded. Practically all of this metal produced in Canada is derived from the copper-nickel ores of the Sudbury district, Ontario. Nickel sulphide made at Copper Cliff by the International Nickel Co. of Canada, Ltd., is shipped to the company's nickel refinery at Port Colborne, Ontario, to be reduced to nickel metal, nickel oxide, and nickel salts. Nickel is also made at Clydach, Wales, from a nickel sulphide which has been partly processed at Port Colborne. This company also operates a smelter at Coniston, about eight miles east of Sudbury, producing various grades of matte. That part of the high-grade matte which is in the ratio of 1 copper to 2 of nickel is shipped to Huntingdon, West Virginia, for the production of Monel metal. Nickel-copper matte produced at the smelter of the Falconbridge Mines, Falconbridge, is shipped to the company's refinery at Kristiansand, Norway, for treatment. Development work was carried on at several other nickel deposits in Canada, and the B.C. Nickel Mines, Ltd., at Choate, British Columbia, exported concentrates for experimental purposes.

The Protection of Aluminium Base Alloys Against Outside Atmospheric Exposure

By E. ARMSTRONG

The advantages of synthetic organic finishing media for the protection of aluminium base alloys are discussed. Methods of cleaning and applying the finish are reviewed and the merits of certain classes of finishing media are emphasised, particularly with regard to finishing time and production, under conditions of atmospheric exposure.

THE light alloys of the aluminium group figure prominently among the metals of construction employed by nearly every engineering concern. Physical lightness is perhaps the primary reason. Comparatively good resistance to corrosion is a second strong feature, and where corrosion does occur, the products are usually white or light coloured with considerably less appearance-detracting propensities than those of iron, which often produce dark brown, adherent stains, even where they become washed down over the portions of the finish which are still sound. To the latter sentence perhaps should be added a warning that the corrosion resistance of aluminium alloys varies rather widely with their composition, as well as in some measure with the physical condition and quality of the component concerned, so that it behoves the engineer to make a wise selection.

A third reason for the popularity of the aluminium alloys centres in the diversity of types freely available. Sheet, rod, tube, section, and castings can be procured in many compositions, giving a field from which to secure appropriate proof stress or ductility, accuracy of dimensions or heat-treatability, resistance to fatigue or to corrosion, and special amenability to deep drawing or to high-speed machining. No really special technique is entailed in engineering fabrication processes, beyond attention to clearances in press tools, cutting angles, and heat-treatment temperatures, all of which are special for the various metals ordinarily utilised in any case.

Generally, the last phase of manufacture that articles have to pass through is the " finishing " one. Here again, there is nothing strange to the normal metal-finishing department with respect to mode of handling although precautions have to be observed and additionally a few specific procedures are of particular advantage. Solvent and vapour degreasing, mild alkali cleaning, polishing, buffing or grinding, lacquering and enamelling can follow along regular lines. At the same time, electro-plating must be preceded by specialised immersion treatments, such as the ferric chloride dip, or closely similar manganese or nickel dips. Again, protective treatments by chemical immersion processes or by electrolytic anodisation methods characterise this particular series of alloys and although they demand skill and control for their successful execution, they involve nothing beyond the ability of the ordinary finishing shop foreman and his operators. The subject of this article is confined to the finishing of aluminium or its alloys in the form of components with organic media, that is, enamelling or painting. Obviously, from the foregoing, nothing revolutionary will be revealed because the methods of cleaning and applying the finish, as well as the media themselves, will be commonly recognised. Rather will the subject be confined to establishing the merits of certain classes of " synthetic " media with respect to finishing time, and therefore with relation to production under conditions of outside atmospheric exposure.

It must be stressed at the outset that the finish for the aluminium light alloys that most nearly approached the ideal is anodic oxidation. This provides a weather-proof surface film, and with suitable processing can be produced to resist attack by sea water or by industrial atmospheres, while again the appearance aspect of this form of finishing is not confined to the colour in which the work is withdrawn from the electrolytic bath, but the coating may be dyed in one of an almost unlimited range of colours with the exception of white. It is therefore, with no intention of belittling the merits of anodic protection that the attributes of synthetic organic finishes are put forward. There are and always will be, numerous occasions upon which anodising cannot be contemplated for one reason or another. Some alloys do not lend themselves efficiently to this means of treatment, while others demand specialised procedures. Plant is not always available to handle the particular shape or size of object. The article may be of an intricacy that renders it difficult or impossible under production conditions to wash the electrolyte thoroughly from recesses or holes. It is evident therefore, that organic finishing which only demands the regular spraying equipment of hoods and spray stations, and of stoves where baked finishes can be contemplated, and for which chemical solutions for surface preparations may be entirely avoided, must be regarded as a useful counterpart to anodising and not as a rival.

The term " organic finishing " is one conveniently employed to embrace all the nondescripts such as lacquering, varnishing, enamelling and painting, as there is much overlapping in the use of these terms, and they have in consequence little real significance in industrial finishing. What is really implied amounts to the efficient application of a number of coats of organic medium, with appropriate drying time between each. The drying may be an air-drying period, a forced dry at low temperature or a stove treatment. The work to be finished may be sheet presenting in the main the smooth surface as leaving the rolls, likewise in the case of tube or rod, whereas, in the latter form, subsequent machining may have been carried out, but still leaving a relatively difficult surface for good keying of the organic finish. Castings are generally rougher, but these may have passed through scurfing or milling operations. In all cases, machine shop greases, oil and swarfe will be present. The finishing shop operations must, then, necessarily embrace the following :—

1. Cleaning to remove all loose extraneous matter, oil, grease, dirt, swarfe, etc.
2. Surface preparation, not always, but in certain cases, to remove casting fins, etc. and always when the utmost is demanded of the finish.
3. Priming or undercoating.
4. Surfacing and filling for rough components.
5. Finishing coats.

The first two items will be common to all types of finish, whether cellulose, oil or synthetic, and will accordingly be dealt with first.

If chemical solutions are to be avoided, and this is a highly desirable feature when practicable, solvent cleaning can always be called upon. Trichlorethylene degreasing in solvent or vapour, or preferably both, is efficient for most types of contamination, and if the work is too large to be accommodated in available plant, it can be cleaned with solvent naphtha using a swab. If any signs of corrosion are evident, the work should be scrubbed bright with a wire brush.

If local conditions render it necessary or advisable, chemical cleansers can safely be resorted to providing after-washing with cold and hot water is carried out with meticulous care. A hot solution containing 4 oz. each of sodium metaphosphate and sodium carbonate per gallon represents a good general purposes cleanser.

It is useful to note that when alkaline degreasing is carried out, generally it is worth while including an aqueous chemical chromate treatment in the same chain of operations. This adds to the corrosion resistivity as well as improving the adhesion of the organic finish, while at the same time the expense of its inclusion is small in relation to total finishing cost. A typical serviceable solution is that known as MBV., comprising 5% soda ash and 1·5% sodium chromate per gallon of water. It is operated hot and immersion time may be from 3 to 15 minutes. Its beneficial effect are most marked with commercial aluminium or with the various aluminium alloys containing magnesium. In the case of the high copper content alloys (e.g., duralumin) or high silicon ores (e.g., 10% silicon) a slight loose film may be produced although this does not seem detrimental to the applied finish.

Scurfing by grinding is necessary on large castings in many applications and calls for no comment. Surface roughening by sand- or shot-blasting need not be essential with the right selection of finishing media, although it is always advantageous. With cellulose finishes applied direct to the metal without oil or synthetic primers, such roughening is considered indispensable, although again this type of finish is not advocated for external work if any appreciable length of service is anticipated. All finishes, however, harden up to a greater or lesser degree, and become less flexible, more prone to damage from impact, shock, vibration or temperature fluctuations. The sand- or shot-blast operations adds measurably to the service life of the finish by providing a key, the tenacity of which is retained for extended periods under these conditions which gradually assert their influence more and more as the finish ages. It is desirable that the pressure of the blast should be as light as possible, something in the neighbourhood of 5 lb./sq. in. air pressure being suggested. Very thin sections or fragile castings cannot be so treated on account of distortion.

Turning now to the finishing operations proper, viz., Nos. 3, 4 and 5, these perhaps can most concisely be treated separately under the following headings, which cover the obvious possible choices :—

(*a*) Air drying finish, using normal oil base media.
(*b*) Stove finish, using normal oil base media.
(*c*) Straight cellulose finish.
(*d*) Combination oil and cellulose finish, all coats air dried.
(*e*) Air drying, finish, using synthetic media.
(*f*) Stoved finish, using synthetic media.
(*g*) Combination finish, using stoved synthetic primer and surfacer, and air dried or force dried cellulose finishing coats.

Each class of finish has its advantage and disadvantage, especially when it is borne in mind that factors of cost, time period for execution and availability of equipment are all criteria for consideration in addition to durability of the finish itself. The stoved synthetic finish (*f*) stands out as undoubtedly the finest of all, with the air-dried synthetic (*e*) and the combination finish (*g*) as also first-class productions. However, the merits and demerits of each will clearly be indicated below. At the same time, it is opportune at this stage to stress that whatever the finishing medium in question, there are various qualities marketed, and the best results can only be obtained with the best materials. These are not necessarily those bearing the highest price per gallon, and correct selection can only be assured on test results. Sprayed panels must be assessed for adhesion, ageing qualities, and durability, and this section of the testing can conveniently be combined with evaluation of spraying characteristics, flow, drying time, etc. This aspect will not be referred to again, but it must be borne in mind with respect to each material subsequently mentioned, for it will be assumed that each product dealt with does conform to requirements in these directions.

Briefly tabulated below are the operations entailed for typical spray finishes applicable to the usual wide range of colours encountered.

(*a*) *Air Drying Oil Base Finish.*

1. Spray one coat red oxide primer.
2. Allow 8 hours minimum drying time.
3. Fill pits, pores, etc. in castings with paste filler.
4. Allow 2 hours minimum drying time.
5. Spray one coat of surfacer.
6. Allow 6 hours minimum drying time.
7 and 8. If necessary, spray further coat of surfacer, and allow 6 hours for drying.
9. Lightly flat with abrasive paper.
10. Spray one thin coat of finishing enamel.
11. Allow 12 hours minimum drying time.
12. Spray a full coat of finishing enamel.
13. Allow 24 hours minimum drying time.
14. Spray one coat of weather-resisting varnish.
15. Allow 48 hours minimum drying time prior to packing or shipping.

(*b*) *Stoved Oil Base Finish.*

1. Spray on coat red oxide primer.
2. Stove 1 hour at 250° F.
3. Fill in pits, pores, etc. in castings with paste filler.
4 Stove 1 hour at 250° F.
5. Spray one full coat of surfacer.
6. Stove 1 hour at 250° F.
7 and 8. If necessary, repeat 5 and 6.
9. Lightly flat with abrasive paper.
10. Spray one thin coat of finishing enamel.
11. Stove 3 to 4 hours at 200° F. or 1½ to 2 hours at 250° F.
12. Spray full coat of finishing enamel.
13. Stove 3 to 4 hours at 200 °F. or 1½ to 2 hours at 250° F.
14. If necessary, spray one coat of weather-resisting varnish.
15. Stove 3 to 4 hours at 200° F. or 1½ to 2 hours at 250° F.

(*c*) *Straight Cellulose Finish* (*only useful on sand- or shot-blasted surfaces, on anodised or chromated surfaces*).

1. Apply first coat cellulose enamel.
2. Allow 4 hours minimum drying time.
3, 4 and 5. If necessary repeat 1 and 2, and lightly flat with abrasive paper.
6. Apply final coat of cellulose enamel.
7. Allow 24 hours minimum air drying prior to shipment or packing.

(*d*) *Combination Oil/Cellulose Finish.*

1. Spray one coat red oxide primer.
2. Allow 12 hours minimum drying time.
3. Fill in pits, pores, etc. in castings with paste filler.
4. Allow 2 hours minimum drying time.
5. Spray one coat paste oil sealer.
6. Allow minimum 4 hours drying time.
7. Lightly flat with abrasive paper, avoiding cutting through to the oxide primer.
8, 9 and 10. If necessary, repeat, 5, 6 and 7.
11. Spray first coat of finishing cellulose enamel very thinly and avoiding applying it excessively "wet."
12. Allow 4 hours minimum drying time.
13 and 14. Repeat 11 and 12.
15. Spray full coat of finishing cellulose enamel.
16. Allow 24 hours before packing or shipment.

(*e*) *Air Drying Synthetic Finish.*

1. Spray one coat synthetic red oxide primer.
2. Allow minimum drying time 4 hours.
3. Fill in pits, pores, etc. in castings with synthetic stopper.
4. Allow 2 hours minimum drying time.
5. Spray one coat synthetic surfacer.
6. Allow 4 hours minimum drying time.
7 and 8. If necessary, repeat 5 and 6.
9. Lightly flat with abrasive paper.
10. Spray mist coat of synthetic finishing enamel.
11. Allow 1 hour minimum drying time.
12. Spray full coat synthetic finishing enamel.
13. Allow to dry 24 hours before packing or shipping.

(*f*) *Stoved Synthetic Finish.*

1. Spray one coat synthetic red oxide primer.
2. Stove 1½ hours at 200° F. or ½ hour at 250° F.
3. Fill pits with synthetic stopper.
4. Air dry for 10 to 15 minutes.
5. Spray one full coat synthetic surfacer.
6. Air dry for 10 to 15 minutes.
7 and 8. Repeat 5 and 6 if necessary.
9. Stove for 1 hour at 200° F. or ½ hour at 250° F.

10. Lightly flat with abrasive paper.
11. Spray one thin coat synthetic finishing enamel.
12. Stove for 1 to 2 hours at 200° F. or ½ to 1 hour at 250° F.
13. Spray one full coat synthetic finishing enamel.
14. Stove for 1 to 2 hours at 200° F. or ½ to 1 hour at 250° F.

(*g*) *Combination Finish, Stoved Synthetic Groundwork, Cellulose Finishing Coats.*

Operations Nos. 1 to 10 inclusive, are as for finish (*f*).
11. Spray one full coat of cellulose enamel.
12. Allow 4 hours minimum air drying.
13. Spray second coat of cellulose enamel.
14. Either allow 24 hours air drying prior to packing or shipping or allow 4 hours air drying followed by 1 to 2 hours at 140/150° F. forced drying.

Next, a few brief comments are called for upon the media referred to themselves.

Two types of primer, oil or synthetic, have proved particularly suitable for the ground coat on light alloys, viz., red oxide of iron and yellow zonc chromate varieties. In the writer's experience, the former has given every satisfaction, but under extreme conditions of severity, it is believed that zinc chromate primers yield even superior performance. Preference is given to primers in which the ratio of mineral pigment to binding vehicle is not unduly great, as distinct from typical highly pigmented undercoats. No hard-and-fast rules for composition can be given, nor would they be wise, selection by performance being preferred and furthermore, efficiency is dependent upon so many factors in the make-up of the medium other than actual composition.

The paste fillers or stoppers are critical items if they are not to provide points of weakness in the finish during service. While rapid hardening or drying is an essential characteristic, initial tests must safeguard that shrinkage away from the surface filled does not occur.

Perhaps the most important special feature to examine in the surfacer, is the degree of sinkage of the subsequent finishing coats. The synthetic surfaces are particularly good in this respect.

The weather-proof varnish is really necessary on the air-drying oil finishes under open exposure conditions for the preservation of gloss and protection against chalking. It is likewise an asset on the stoved oil finishes. On the synthetics it can be dispensed with quite safely, and if employed to add to the gloss it generally may replace one of the finish coats of enamel. This applies to stoved and air-drying synthetics.

In the case of the cellulose finishes, the final enamel coat can be replaced by a clear lacquer coat, colourless or tinted to the hue of the base enamel. The paste-sealer referred to in class (*d*) possesses an exceptionally high pigment/oil ratio and is intended to isolate the oil primer from the cellulose top coats.

To convey some impression of the nature of these finishing media, test values are given in Tables A, B, and C. The volatile carrier and total solid values are the loss and residue respectively determined in the British Standard manner of heating a weighed quantity in an aluminium dish for 3 hours at 110° C. Specific gravities were determined by the bottle method and viscosities by means of the British Standard U-tubes or Ford cup.

The above detailed presentation of the various finishing schemes has been designed to show rapidly the coatings required and the times involved with respect to drying or stoving. Other combinations are practicable, typical examples having been selected. Also, the *maximum* required by each class has been given. Thus for sheet work of good surface, filling and surfacing may be dispensed with, whereas it is indispensable in the case of castings. Again, consideration has been in terms of the best demanded for severe service, whereas particular local conditions may quite well permit of omitting one of the finishing coats, while again competitive manufacture sometimes demands a single coat all told. Obviously, the latter circumstance takes the matter out of the present discussion, but it can be stressed in passing that certain of the synthetics demand attention when conditions of this kind have to be catered for.

TABLE A.

TEST VALUES ON UNDERCOATING MEDIA.

Sample No.	Type	Volatile Carrier %	Total Solids %	Specific Gravity at 70° F.	Viscosity centi-poises at 70° F.	Ratio of pig-ment to binder
1	Air drying Red oxide primer, oil base	49·0	51·0	1·050	430	1/1
2	Stove Red oxide primer, oil base	48·5	51·5	1·065	475	1/1
3	Air drying Synthetic Red oxide primer	31·5	68·5	1·542	500	3/1
4	Stove Synthetic Red oxide primer	30·9	69·1	1·540	495	3/1
5	Stove Synthetic Zinc Chromate primer..	55.5	45.5	1.30	300	1/1
6	Air drying grey surfacer, oil base	19·8	80·2	—	—	9/1
7	Stove Grey surfacer, oil base	22·5	78·5	—	—	8/1
8	Air drying synthetic grey surfacer	32·5	67·5	1·455	1,750	4/1
9	Stove synthetic grey surfacer	27·4	72·6	1·605	350	3·5/1
10	Paste filler, air drying oil base	6·4	93·6	—	—	8/1
11	Paste filler, stove oil base	7·5	92·5	—	—	9/1
12	Paste filler, air drying synthetic	8·5	91·5	—	—	5/1
13	Paste filler, stove synthetic	9·5	90·5	—	—	7/1

TABLE B.

TEST VALUES ON PASTE OIL SEALERS FOR AIR DRYING OIL/CELLULOSE FINISHES.

Sample No.	Pigment %	Drying Oil %	Volatile Carrier %
1	76·0	6·1	17·9
2	83·4	6·5	10·1

Pigment consisted of lithopone, tinted grey with a black lake.
Carrier consisted of white spirit.

TABLE C.

TEST VALUES ON FINISHING COAT MEDIA.

Sample No.	Type	Volatile Carrier %	Total Solids %	Specific Gravity at 70° F.	Viscosity in centipoises at 70° F.
1	Air drying oil base enamel.				
(*a*)	Red	35·2	64·8	0·918	465
(*b*)	Grey	25·2	74·8	1·307	1,650
(*c*)	Mahogany	32·5	67·5	1·440	300
2	Stove oil base enamel.				
(*a*)	Brown	20·5	79·5	1·470	475
(*b*)	Grey	22·5	77·5	1·605	400
3	Air drying weather resisting oil varnish	38·4	62·6	0·905	465
4	Stove weather resisting oil varnish	63·7	36·3	0·873	375
5	Cellulose Enamel.				
(*a*)	Red	69·5	30·5	0·994	5,200
(*b*)	Blue	63·3	36·7	1·045	650
(*c*)	Green	65·0	35·0	1·050	1,470
6	Air Drying Synthetic.				
(*a*)	Red	52·5	47·5	0·970	960
(*b*)	Blue	57·4	42·6	0·947	300
(*c*)	Green	54·6	45·4	0·943	345
7	Stove Synthetic.				
(*a*)	Blue	41·0	59·0	1·084	225
(*b*)	Red	49·8	50·2	0·955	285
(*c*)	White	40·0	60·0	1·260	410

Critically comparing the finishes, the following brief comments ensue :—

(*a*) *Air Drying Oil Base Finish.*
This is exceedingly slow to execute because of the prolonged drying periods. On the other hand it is sound and gives extended service. In one experience, a cast aluminium street equipment at a seaboard town, the finish withstood five years' exposure before renewal. Its condition was then such that entirely cleaning-off was advisable.

(*b*) *Stoved Oil Base Finish.*
More rapid execution is the only advantage of this over (*a*).

(*c*) *Straight Cellulose Finish.*
This is only included because it is employed on occasion on account of speedy drying and because stoving equipment is not available. It is not recommended for open weather conditions.

(*d*) *Combination Oil/Cellulose Finish.*
This provides a good compromise with respect to

time of execution between the air-drying oil finish (*a*) and the straight cellulose finish (*c*). Considerable skill needs to be developed in its application, chiefly, it seems, with respect to retaining the oil priming coat as thin as possible, and the cellulose coats from going on to wet and thereby penetrating right through the sealer. Experiences have shown the finish to withstand four to five years' service in industrial towns, with, of course, periodic cleaning to wash off dirt and soot. On the other hand, failures have occurred within a year. It does not therefore, seem so reliable as (*a*) or (*b*), nor does it withstand severe tropical conditions, again in contrast to the oil base finishes.

(*e*) *Air Drying Synthetic Finish.*

It will be noted that this is definitely quicker in execution than the corresponding oil finish, and additionally the final coating of varnish is not included. Evidence goes to show up to the present that such a finish should withstand longer exposure periods than the ordinary oil type of finish.

(*f*) *Stoved Synthetic Finish.*

Practical experience shows this to be the most superior of the finishes. It will be seen that not only are stoving times much shorter than for the oil stoved finish, but that the surfacings and filler can all be stoved in one operation. Also, the shorter stovings render these finishing media much more adaptable to conveyerised enamelling plants than is the case with oil enamels. Alternatively, it may be said that costly mechanised enamelling stoves can more readily be justified for short stove synthetics than for oil enamels because their size can be approximately halved.

(*g*) *Combination Finish, Stoved Synthetic, Cellulose Finishing Coats.*

This is an extensively used finish but it has not logically any advantage from view points of convenience or speed over the fully stoved synthetic. Nor will it possess the same durability under service exposure conditions.

The finishes advocated are of the selected synthetic type, either glyptal or urea resin base. Stoved finishes are urged, but where equipment is not available or the work is too massive for handling in this way, air drying synthetics are recommended. Castings demand surfacing and filling in addition to priming and finishing coats, but sheet work requires only priming and finishing materials. Competitive work can safely be allowed a total of two coats, and in extreme cases, a single coating. The little higher initial cost of first-class synthetics is more than offset by the greater speed of execution and by improved service behaviour.

Finally, some outstanding salt spray test results (8 hours spray, 16 hours in the test cabinet without spray operating) are worthy of mention.

The samples exposed consisted of the following :—

1. An aluminium silicon alloy casting sand-blasted and finished with red oxide primer, grey surfacer and two coats of red, all stoved synthetics.
2. Two coats of air-dried red synthetic enamel direct on hard aluminium sheet without sand-blasting.
3. Two coats of stoved red synthetic enamel direct on hard aluminium sheet without sand-blasting.
4. Red oxide primer, grey surfacer and two coats of red synthetic enamel stoved on hard aluminium sheet without sand-blasting.
5. As for No. 4, except red oxide replaced by zinc chromate primer.

Exposure period was two years, and appearance was unchanged, gloss, colour and hardness being unimpaired. With respect to ageing, the finishes were still exceptionally good for resistance to scratching, and only a little flaking occurred on bending, this flaking not extending to the unbent portion of the specimens.

The media used in the preparation of the test panels were those illustrated in the tabulated data. It is considered that pre-eminence of synthetics for providing finishes that are both decorative and protecting, and serviceable over extended periods, is an established fact.

Fuels of Today and Tomorrow

INCREASED efficiency in the use of coal and the displacing effect of petroleum and of natural gas has caused a steady decline in the proportion of energy obtained from coal said Dr. A. C. Fieldner, in a recent address at the University of Maryland. He pointed out that thirty years ago, coal supplied 89 per cent. of the fuel energy of the United States ; to-day coal supplies only 50 per cent. The rise in the use of petroleum fuels may be attributed to the demand for liquid fuel created by the great development of automotive transportation, which resulted in a large supply of fuel oil which sought and obtained a market in competition with coal. An inventory has been made of the national fuel reserves and it is pointed out that the United States produced and consumed 31 to 33 per cent. of the world's production of coal, 60 to 70 per cent. of the petroleum, and 95 per cent. of the natural gas. A little over one-half of the world's reserves of coal and probably 60 per cent. of the proved oil reserves are in the United States. The oil in the ground recoverable by current methods of production in the United States has been estimated at 13 billion barrels, but in the last three years discovery of new fields has kept pace with production, so that the reserve appears to remain approximately constant. It is impossible to forecast future rates of discovery and opinions differ as to when a decline will begin. Regardless of whether it may begin within one or several decades, the United States oil and gas reserves are small compared to coal.

An appraisal of present trends and future probabilities of fuels of to-morrow indicates that coal will continue to be the principal fuel used for the generation of public utility and major industrial power. The convenience and the uniformity of automatic heating of homes with gas and oil will continue to attract more users, even at higher prices, than those prevailing to-day. However, stoker-fired domestic furnaces eventually will give automatic service at a lower cost than that of oil and gas. On the whole, coal, because it is the cheapest fuel, will continue to contribute the major portion of the fuel used in house-heating. It is expected that further improvements in the overall efficiency of the steam locomotive and a gradual increase of electrification will retain the use of coal for freight traffic even though the Diesel locomotive may become increasingly popular for high-speed passenger trains.

Research on the refining of petroleum has been stimulated by the 10 to 12 million dollars spent annually. Even more should be expended on research for the preparation and utilisation of coal if it is to regain its former title—King Coal—the undisputed monarch of the fuel world.

Canada possesses active and potential resources of the ores of copper, nickel, lead and zinc, sufficient to meet her own needs and a large share of the world requirements for many years to come. She is now supplying close to 90% of the world's nickel, 11% of the copper and lead, and 10% of the zinc requirements. The four chief producers of base metals in Canada are Consolidated Mining and Smelting Company, British Columbia, Hudson Bay Mining and Smelting Company, at Flin Flon, in Manitoba, International Nickel Company, in Ontario, and Noranda Mines. Limited, in Quebec. These companies produced more than 90% of Canada's total output of base metals in 1937.

Controlling "Controlled Atmospheres"

The Brown Analy-Graph

Accuracy in the measurement of temperature and close control of the rate of heating and cooling have long been the sole criteria of heat-treating, but a fast growing fund of knowledge concerning the real causes of scaling, carburisation, decarburisation—methods of control or prevention, etc.—emphasises the importance of a third factor—furnace atmosphere, and a long step towards perfection in this respect is the recent development of a furnace atmosphere measuring and recording apparatus which is described.

IN recent years much attention has been given to the need for control in heat-treatment operations. In particular, attention has been directed to uniform temperatures, and, gradually, automatic devices have been perfected for controlling furnace temperatures which are recognised as essential when the nature of the operations and the character of the equipment permit. Although these devices are designed to maintain a required temperature in a furnace within comparatively narrow limits, the primary object is to heat the articles being treated to the desired temperature with a view to obtaining uniformity in the finished product, and a uniform temperature in the furnace is necessary for this purpose.

The problem of uniformity in heat-treatment, however, has a much wider significance than the control of temperature; several other factors, which affect the quality of the heat-treated product, are involved, not the least important of which is the atmosphere which surrounds the product under treatment. Frequently, in fact, control of the atmosphere which surrounds products when being heat-treated, is just as important as control of the furnace temperature. Much has been said about controlled furnace atmospheres and it seems to be generally recognised that the best results in preheating, hardening, tempering, normalising, carburising, etc., are obtained where special gas atmospheres surround the components undergoing any particular type of heat-treatment. Agreement has not yet been reached, however, on what constitutes the proper atmosphere for any given metal, or alloy.

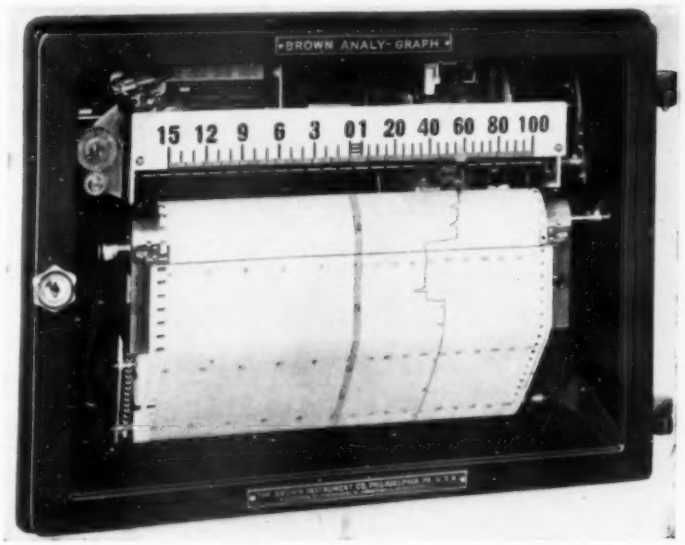


Fig. 1.—Recorder which continuously records atmospheres produced by any degree of combustion—from partial to complete—on a chart 12-in. wide.

Many tests have been undertaken, and the results used as a basis in determining the most suitable atmosphere for a given material, but few data are available which state the relative quantities of all gases present. This situation is undoubtedly due to the difficulty of obtaining a complete analysis of furnace atmospheres in the average heat-treatment plant. In many instances atmospheres are tested by the oldest method that of trial and error, a method which can be regarded as expensive and frequently difficult to repeat to obtain the degree of uniformity needed.

In attempting to remedy this situation, a series of tests have been undertaken to determine those characteristics of furnace atmospheres which can best be used as a means of measuring the conditions existing in a furnace, for, obviously, in order to control, it is first necessary to measure. These tests, which are described by Krogh,* revealed considerable data. The purposes of the tests were to determine the measurable properties of furnace atmospheres; to determine the most significant of these; and to devise means of continuously measuring and recording this property.

As a basic part of the investigation, it was decided to provide a record of the thermal conductivity of the gases. Thermal conductivity meters are based upon the ability of heat to flow through a gas mixture. Such meters usually take the form of a Wheatstone bridge, of which two or more arms are made from wire having a high temperature coefficient. Each of these arms or filaments is enclosed in a cellular space, and current is passed through the bridge to heat the filaments. In one cell is sealed air, while the sample gas is passed through the other. As the composition of the gas sample changes, the relative temperature of the exposed filament changes—thus changing its resistance, and unbalancing the Wheatstone bridge. The amount of this unbalance may then be measured. Analysis equipment for this purpose was incorporated in the test, and a graphic record produced on a potentiometer. This instrument proved so useful during the tests and in subsequent production work that a device based on this principle, and called the "Furnace Atmosphere Analy-Graph" resulted. The instrument developed in this way is shown in Fig. 1.

In the consideration of common atmospheres derived by partial combustion of industrial gases, most authorities agree that a CO_2/CO ratio will, if large, cause decarburisation and scaling of steel. If very small, both of these actions will be reversed. In an intermediate range, carburisation and scaling may occur simultaneously due to these gases. A CH_4/H_2 ratio, if large, will cause carburisation of steel. If very small this action will be reversed. An H_2O/H_2 ratio, if large, will cause scaling of steel. If small, this action will be reversed.

In controlling these ratios in the active zone of the furnace, several factors have to be considered when a fuel gas is partly burnt with a deficiency of air, and partly

* A. E. Krogh, *Metals and Alloys*, Feb. and March, 1937.

cracked, as is the case in the preparation of the usual commercial atmospheres. Among these are the initial composition of the fuel gas, the humidity of the air, the gas/air ratio, the rate of flow, the temperature of the pre-combustion and cracking chamber, the presence or absence of catalysts there, the completeness of dehydration of the gas before it enters the furnace proper, the combustion of the gas at this stage, the rate of flow, the temperature of the furnace, and the catalytic effect of the charge and the furnace walls.

After the fuel gas is chosen and the temperature of the furnace proper is fixed, the factors under the most ready control are the gas/air ratio and the temperature of the pre-combustion chamber. Slight changes in the gas/air ratio, in the ranges usually employed, produce quite large changes in the composition of the exit gas from the pre-combustion chamber, so that the pressure guages always employed may not allow a sufficiently fine adjustment. It is here that the "Analy-Graph" allows finer adjustment, and provides information on the effect of the temperature of the pre-combustion chamber, so that, if necessary, that also may be adjusted. In this way the furnace operator has the advantage of duplicating with greater certainty a gas composition which has been found suitable for the work in hand.

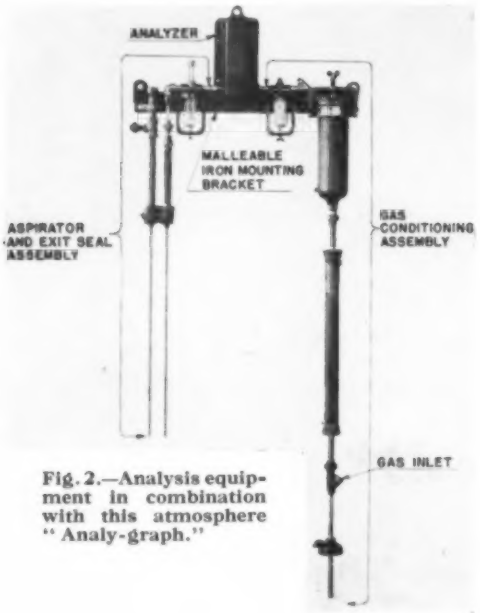


Fig. 2.—Analysis equipment in combination with this atmosphere "Analy-graph."

A gas analysis equipment used in combination with the furnace atmosphere "Analy-Graph" is shown in Fig. 2. Samples of gas may be taken where desired—in the furnace, the recuperators, the ducts, the retorts, etc. Accuracy starts with the collection of the sample atmosphere surrounding the metal being treated. Except that it may affect the quality or composition of the atmosphere before sampling is done, temperature has no influence on the analysing process. Continuous recording is accomplished by installing an inert sampling tube at a point where it will not interfere with furnace handling operations. A small, steady flow of furnace atmosphere is drawn through filtering and drying units, and then into the gas analysis cell. Here quantities of the gas mixture are used to determine the atmosphere's metallurgical effectiveness and are translated into electrical terms for transmission to the measuring and recording instrument shown in Fig. 1.

This instrument is equipped with a powerful motor drive and sensitive galvanometer, the slightest fluctuations of atmosphere quality are traced with great clearness on a chart 12 in. wide. Direct indicating, it will be noted, is done on a separate scale.

With fuel-fired furnaces, all stages of combustion are visualised by this instrument—from partial burning where carbon monoxide (CO) may be in excess of 20%, to complete combustion with excess oxygen (O_2). Both indicator and graduated charts are divided at the middle to show clearly which stage of combustion has produced the furnace atmosphere under observation. A narrow band separates the two sections and shows a condition of combustion that is known to be very unstable; hence, there is uncalibrated strip, $\frac{1}{8}$ in. wide, in the centre of the chart.

Recording is in terms that furnace operators can put to immediate practical use. No knowledge of chemistry is required. Conditions of complete combustion are covered by the left half of the scale calibrated in percentage of carbon dioxide. The incomplete combustion section on the right, instead of percentage, is calibrated from 1 to 100 in accordance with best metallurgical knowledge—every indication showing that the effectiveness of atmospheres produced by incomplete combustion depends upon a number of factors, not one of which alone is suitable for use as an indicator. The operator determines what the instrument should read for various metals, furnace temperatures and time schedules to produce the heat-treatment desired. Fuel and air are then controlled to maintain the instrument reading desired.

Most of the troubles associated with furnace atmosphere vanish when definite knowledge replaces guesswork. Heat-treatment operators can concentrate on getting and maintaining all the conditions needed for perfect work. If, in addition to the atmosphere "Analy-Graph," automatic temperature control is used and time schedules are strictly maintained, the only chance of failure will be carelessness or a breakdown of the atmosphere supply.

Designed and manufactured by Honeywell-Brown Ltd., 70, St. Thomas Street, London, S.E.1, this equipment is available for installation in connection with all types of furnace—gas, oil or electric. With or without separate automatic temperature control, it is now being used successfully for normalising, slab heating, pre-heating, hardening, tempering and carburising furnaces; for gas preparation machines, soaking pits, malleablising and brazing (with less than 50s of pure hydrogen).

Whether or not a controlled atmosphere is desired, this instrument is a convenient and accurate means for determining the degrees of combustion in fuel-fired equipment of all types used in production work.

British Foundry School

THE Governors of the British Foundry School at Birmingham announce that the fourth session of the School will open on September 20, 1938. The present session will conclude at the end of July. The course is for one academic year, and is intended for men of some practical experience and technical training, preparing for higher responsibilities in the foundry industry, and includes cast and malleable cast iron, steel and non-ferrous metals. Further information and forms of application may be obtained from the Secretary of the School, at the Centrai Technical College, Birmingham, or from the Hon. Treasury and Adviser, 21 St. Paul's Square, Birmingham, 3.

"A Guide to the Right Electrode for Electric Arc Welding" has been published by Murex Welding Processes Limited; to meet, it is stated, the demand for greater efficiency and the increase in the field of application of the electric arc process which has resulted in the production of a very large range of electrodes.

The information contained in this booklet should guide the user in the selection of the correct type of electrode. It also gives useful information on correct methods of application and procedure.

There are general instructions, tabulated recommendations for the many types of electrode and the body of the book is devoted to description and characteristics of the various Murex electrodes, forming very useful data indeed.

Copies can be obtained from the Publicity Department at Ferry Lane Works, Forest Road, London, E. 17.

The Metallurgical Inspection of Steel

By J. S. G. Primrose

There is an ever increasing need for the application of metallurgical inspection on steel in all its forms, properly and whole-heartedly carried out. In a recent lecture before the Midland Section of the Institution of Mechanical Engineers, the author selected some outstanding examples which can be taken as representative and most significant, the salient features of which are given below.

THE induced grain size of the steel is important to know, and a simple fracture helps to show this, but much more importance is now attached to the inherent grain size of the steel, and already several methods have been suggested in order to determine this. Perhaps the simplest, although not the quickest method, is that which involves the carburising and slow cooling of a test piece. This is followed by a polishing and etching treatment, when the grain size revealed in the " case " can be compared with standards set up by the Association for Testing Materials, and almost universally adopted. The various sizes are designated by numbers from one to eight, and very conveniently replace the old-fashioned method still common on the Continent of referring to coarse, medium or fine grain size. Apart from ensuring a greater degree of uniformity, a knowledge of the inherent grain size is most useful in pre-determining the suitable heat-treatment to be imparted to any given cast of steel to bring about the most desired properties.

The increasingly useful application of what is called macro-etching should not be overlooked, since it shows up the structure as seen by the eye or at any rate under very low power magnification on a polished section which has been deep-etched by suitable reagents to bring up the grain flow or crystal arrangement. " Ghosts " and segregations as well as any severely distorted or crushed portions of the metal are thus clearly revealed, and ought to be appreciated.

Special cases need special precautions which might appear superfluous to most people, but even so theoretical a consideration as taking a spectrographic analysis of each individual bar of valuable alloy steel is common practice to ensure complete absence of mixing and its frequently dire consequences. When an unsuspected flaw is revealed, it is now customary to examine the steel by means of the X-ray shadowgraph method to ensure that there are no more, and in important parts, particularly of welds, it is common practice to have quite a routine examination of work to ensure the rejection of any which is faulty. With sufficiently powerful X-ray apparatus, it is possible to make this a visible operation, but in some cases it is still necessary to resort to long-exposure photographs to get a view of any hidden cavities or flaws including blowholes. Less common is the scattergraph method of space lattice formation, but in certain cases it is useful in determining without cavil the degree of deformation which has been put upon a steel structure subsequent to its last heat-treatment, for instance, annealing, normalising, etc.

Certain special but quite useful tests are those which call for a certain sonority to be given in standard lengths electric spark reaction and for a few purposes, abrasion resistance, but these seldom fall to the lot of the ordinary metallurgical inspector, who however, often makes use of the grinding-wheel spark test for classifying carbon steels by their ascending carbon content according to the branching nature of the incandescent sparks. It might be interesting to note that a recent alloy steel was found to be practically sparkless on a fast-driven carborundum wheel, while certain tool steels give characteristically coloured sparks.

When it comes to acceptance inspection tests, it is quite common to find that this is confined to the Brinell hardness test, which is very convenient in that it can quite easily be made a 100% inspection without damaging or destroying the piece which has been tested. It has its limitations, which in some cases are quite severe, and one of them is that a steel can be made into the required state of hardness by means of cold working, instead of the desired heat-treatment, and so another test is required to supplement the hardness test, either a modified Brinell or preferably an alternative such as the Rockwell cone or the diamond pyramid methods can be used.

Much has recently been written against the tensile test, but there is nothing which completely replaces it for most engineering purposes, and it can be highly informative if only the requisite precautions are taken to ensure a really reliable test with correct ball socket alignments for exact centricity of pulling stress, and more especially a thoroughly trustworthy method of taking completely autographic records of the load extension diagram.

One of the most discussed tests commonly used as an acceptance test is the notched bar impact test as made on a suitable testing machine. The Izod method with slow-moving hammer is practically standardised in this country, but there are numerous other well-known methods of taking higher speed notched bar impact tests. The question in debate at the moment is what does the Izod impact test value indicate; broadly speaking, it informs us whether or not a steel in any particular condition of heat-treatment is liable to fail suddenly under a rapid application of stress, particularly if localised at a notch or surface discontinuity. Really, there are three stages in the fracture of a notched bar, and the Izod test gives us the sum of the three in one value in foot pounds of energy.

What is often used as an arbitration test against the Izod is a slow bend test of a notched bar making a stress-strain curve to indicate the amount of energy absorbed. If a suitably sized bar is chosen, then the area of the curve can be used as an Izod equivalent, and it enables us to discern what part of the energy is required to initiate a crack, how much is needed to propagate it, and the final amount which is needed to complete the fracture in compression. What is almost equally important to watch in the impact test is the appearance of the fracture, for whenever the state of the heat-treatment of the steel is such that a crystalline streak appears, there is a marked drop in the impact value, up to as much as 50%, and the ease with which any initial crack or notch spreads into a fatigue failure is judged to be rapidly accelerated.

Torsion tests are not commonly made in usual routine testing, but, if properly conducted with an autographic record to indicate the yield point, it can be a useful indicator of the power which can be transmitted through a shaft without damage. More commonly applied is the alternate torsion test in which over a given length two complete turns are made, and then it is twisted back again. For revealing under-skin faults in wire it is the most useful test which can be instituted.

A useful method of disclosing minute surface flaws or cracks, particularly if the surface is an interior one, is the so-called magnetic test. When the steel is placed in a sufficiently powerful field, and coated over with a magnetic oxide powder held in suspension in oil, any minute discontinuities present the equivalent of poles and cause the

iron particles to be attracted. They thus build up in a ridge which is quite distinctive, and very useful for detecting faults which are usually beyond the range of ordinary vision.

In spite of all precautions taken, we are constantly coming across failures, from one source or another, and the pathological examination of these is a fruitful source of information, and also forms valuable lessons of what to avoid in the future. Even quite low stressed parts have been known to fail, especially when they have been subjected to a prolonged period of alternating stresses, the magnitude of which may well be within the elastic limit of the material. Such failures we generally find are due to the peculiar phenomenon called "fatigue," and as a rule there is some initial cause which has commenced the trouble. Skin decarburisation, or worse still, slight surface or under-skin discontinuities act as stress raisers, and the state of "triple-tension" sets in, as a result of which the material is unable to move, even though it may be a perfectly ductile steel, and the only alternative is then for it to break with what would otherwise be called a brittle fracture. Once the initial fissure is formed, the continuation of the stressing propagates the crack by creeping, and finally, the area remaining is insufficient to support the load, and the object breaks with a sudden fracture. Apart from putting the steel into its toughest possible condition by achieving a completely sorbitic structure, the best thing to do is to avoid fatigue.

Recent Developments in Tantalum and Columbium

TANTALUM and columbium are produced from the minerals tantalite and columbite by powder metallurgy, workable ingots being made by the heat treatment of bars produced by the compression of the metals while in the powder form. Recent investigations, according to Clarence W. Balke,* show that the carbon content of the finished metal should be below 0·01%, the carbon being removed through the agency of a calculated amount of a suitable oxide mixed with the original powder. Alumina, silica and residual salt are almost completely eliminated during the heat treatment of the bars, this heat treatment being conducted in a vacuum. Although iron cannot be eliminated completely, it is not detrimental if kept below 0·01%; but oxygen has a strongly adverse effect, producing abnormally high hardness, reducing the ductility of the material and increasing the difficulty of annealing.

The final purification of the powder by chemical treatments results in a proportion of hydrogen, which may be as much as 100 volumes, and this affects the pressability of the powder, so that the removal of hydrogen is one of the vital objects of the heat treatment of both metals. Improvement in equipment has made it possible to reduce the final gas pressure at the completion of heat treatment of either tantulum or columbium bars to one micron.

Consideration of grain size is very important. Variations in the grain size influenec the initial electrical conductivity of the bars and the heat gradient from the centre to the surface when the bars are heated as electrical resistances in a vacuum. These considerations demand variation in the heat treatment of every lot of powder.

Columbium is more difficult to produce than tantalum, but recently seamless columbium tubes and large quantities of very thin sheets have been rolled. The clean scrap which accumulates during manufacture was at one time made usable by a chemical solvent process, but a more recent method is to heat the metal in hydrogen at relatively low temperatures and under pressure, the gas entering the lattice and making the metal brittle enough to be pulverised to any degree of fineness; the resulting powder then being treated with acid to remove any iron and then heated to a higher temperature in a vacuum. The individual particles of the reclaimed powder are probably still aggregates and these particles may be of molecular dimensions, as distinct from the original metal produced by electrolysis which consists of crystals of fused and semi-fused globules of solid metal. Adjustment of the heat-treating schedules will, however, remove such differences.

Tantalum is used in the form of wire and thin sheet between 0·004 in. and 0·10 in. The high melting point and low vapour pressure of this metal make it particularly suitable for use in electronic valves for ultra high-frequency radio, and a rapid expansion in the amount of tantalum used in the vacuum valve industry has resulted. Tantalum is such an efficient absorber and keeper of gas, even at pressures as low as 0·001 micron, that the cost of the metal does not miltate against its application.

Among other applications in chemical industries reference is made to the use of tantalum in the form of various types of steam heating equipment, the metal having remarkable resistance to chemical corrosion. Heat transfer through tantalum from steam is unusually great and small heater units can be produced which will do the work of much larger types of heaters and, in comparison with lead, the much greater strength of tantalum enables very thin walled heaters to be used.

Thin walled tantalum tube is used to excellent effect in absorption systems for hydrochloric acid gas, the equipment providing a great saving in space and producing up to 36% acid with cooling water at 87° F. The flexibility of control and capacity of the equipment cited allows for the production of a constant strength acid from a variable gas supply.

Other interesting and practical applications of tantalum include sheet metal for the manufacture of spinning jets for viscose; the covering of pump shafts with seamless tubing or spraying of the shafts with tantalum; as a film forming valve metal with superior dielectric properties for condensers; and carbides of both metals have been used as constituents of hard carbide materials for cutting tools, wire-drawing dies and similar wear-resisting surfaces. Tools containing tantalum and columbium carbides, used for machining steel, have the advantage that they retard chip wear or "cratering." Most makers of sintered carbide tools now make grades containing one or other of these carbides, and a new cast alloy has been developed containing tantalum, tungsten and other elements, to supplement the sintered materials. The alloy has high hardness and admirable resistance to abrasion and corrosion.

* *Ind. Eng. Chem.*, Vol. 30, No. 3, pp 251-4.

Aluminium Activities in Japan

ONE of the prominent firms in the light metal industry in Japan is the Nippon Aluminium Co. Ltd., which originated in 1901, establishing a laboratory at the Osaka factory in 1921. The company purchased from Germany the right to use Jurocker's patent for colouring of aluminium. Present day research appears to have a three-fold purpose: (*a*) to produce an alloy with high tensile strength; (*b*) to develop aluminium alloys with high conductivity; and (*c*) further development regarding non-corrosion and thermal conductivity of aluminium alloys. Recent interesting productions of this company are a tank of pure aluminium, 5·8 metres high and the same diameter, and weighing 5 tons, and of duralumin plates for aircraft work.

High Speed Strip Rolling

By C. E. Davies, M.I.Mech.E.

Progress towards higher rolling speeds has been remarkable during the last ten years, especially in Britain, and the general trend of modern practice was recently discussed by the author before the Midland Metallurgical Society; his views on the subject are given in this article.

IT is opportune to review the question of high-speed rolling of both ferrous and non-ferrous strip metal, especially in view of the remarkable progress made in this country during the last ten years. A decade ago, few men in the cold rolling industry were prepared to consider any mill working at a speed much above 70 ft. per min. The speed at which a mill should run is essentially a matter for those concerned in the actual operation of the plant, but the engineer engaged in the design and construction of rolling plant has perhaps better facilities for noting the general trend of modern practice in this direction.

It is necessary to decide what is really meant by "high speed" as applied to the strip mill, for speed is an entirely relative term and compared with modern hot rolling speeds, those considered high for cold rolling are relatively slow. Twenty-five years ago few mills in this country or the Continent were worked at speeds exceeding 50 to 60 ft. per min., and even now, on the Continent, the classic speed of 65 to 100 ft. per min. is generally considered to be the highest efficient speed. It is perhaps admitted that 100 ft. per min. is a really slow speed, but a high speed may be approaching 1,000 ft. per min. and between these limits there is the large range of medium and high speeds more generally adopted in this country. In the light of development during the last five or six years no speed less than 150 ft. per min. can be classed as high, and the usual range of really high speeeds lies between 200 and 400 ft. per min.

One definition of low speed rolling may be that at which the strip can be gauged during the pass by hand micrometer, and this is somewhere about 150 ft. per min. and certainly not more than 200 ft. per min.

Naturally, the standard of rolling speeds varies with different gauges and qualities of metal, but it cannot be said that the speed for softer non-ferrous metals are generally higher than they are for steel. To-day the maximum finishing speed has increased to 500 ft. per min., and reversing strip mills are operated with a maximum speed of 600 ft. per min. About 1930, the well-known Steckel mill was developed to operate with a maximum speed of about 800 ft. per min. During the early part of the War, a branch works of the American Brass Co. were rolling brass and copper strip at speeds up to 255 ft. per min., and sheets at about 200 ft. per min. These were ordinary heavy two-high mills, with no special features and were mechanically inefficient.

A journey to the States in 1931 and visits to several large brass mills showed the majority of the plants still consisted of similar units, all simple two-high mills, with rolls of large diameter in relation to the work done with high powered motors. 12 × 24 rolls were a common size of finishing mill for brass strip up to 8 in. to 10 in. wide, working at 250 ft. per min. Such mills were driven to death, the white-metal bearings lasted only a few weeks before replacements were necessary, clearly indicating low mechanical efficiency and high loss in bearing friction. Nearly all mills, however, were equipped with automatic coilers and frequently four men were employed at each mill.

At this same time the beginning of the installation of four-high mills was seen, and several such modern mills were working with a variable speed up to 400 ft. per min., also equipped with automatic coilers. Quite recently, in 1936, The American Brass Co. had from very reliable reports, installed four-high mills finishing brass strip, 6 in. or 8 in. wide, at 1,000 ft. per min. It was found impossible to start at the high speed, owing to the difficulty in entering the strip into the automatic coiling equipment, and with the variable speed control provided, rolling on each coil started at 300 to 400 ft. per min., and when once the strip was securely wound on the coiling drum, the speed increased to 1,000 ft. per min.

In Britain, progress towards high speeds lagged behind American practice. In 1921, however, a Birmingham firm installed a British-made mill of American design, two-high, for a speed of 190 ft. per min., but owing to inefficiency of design and consequent high power consumption the speed was reduced to 90 ft. per min. a year or two later. In the same year, a well-known firm in South Wales district put down a plant of 16 two-high mills of small size, for a speed of 100 to 200 ft. per min., for steel strip and a British mill was installed in France for brass strip at about 200 ft. per min. Up to this stage, whilst the practicability of higher rolling speeds was proved, the relative inefficiency and high power consumption with the design then available indicated the need for drastic improvement in the design of cold strip mills, and once the friction losses, particularly in the roll bearings, had been reduced so that they became only a small proportion of the total power applied, and hot-roll bearings were practically eliminated, the proportion of high-speed mills in England steadily increased.

This epoch started with the insatllation and successful working of two highly efficient two-high strip mills for brass by another old-established Birmingham firm with a fixed speed of 260 ft. per min., and with automatic coiling for brass strip, and another firm in Staffordshire district commenced to put down a series of high speed mills for steel strip, starting with 120 ft. per min., and gradually increasing with later units to 250 ft. per min., culminating just recently in a four-high mill with variable speed, and a maximum speed of 400 ft. per min.

In the meantime, many non-ferrous metal works in this district followed with high speed mills, with speeds of 150 to 300 ft. per min., and the same firm, who in 1921 started an American type mill, and who were obliged to reduce this speed, scrapped the whole of their fifteen-year-old slow speed plant and installed a complete installation of high speed mills for breaking down to finishing, with automatic coiling and speed up to 300 ft. per min., and other steel strip firms started up modern high speed units.

All this time, on the Continent, where German practice in mill construction had paramount influence, low speeds of 20 to 30 metres per minute remained, and to some extent remain the rule. This is rather surprising, unless it is remembered that the standard type of two-high mill in vogue on the Continent is not suitable or efficient at higher speeds. Although now some high speed mills are being built in Germany, as a result of this conservative attitude British-built high speed mills, both two-high and four-high, have been installed in France, Belgium and other countries, during the last five or six years. Now there are a number of four-high steel strip mills working successfully in French works at speeds up to 120 metres per min., with similar plants in Belgium, where, also two-high non-ferrous strip mills are in regular operation at 300 ft. per min.

It is especially strange that the very considerable and important aluminium industry in France, Switzerland and Germany do not appear to have appreciated the economy from high speed mills, in spite of the success obtained with such mills on aluminium strip in America, Canada and this country, where speeds of 150 to 250 ft. per min. are quite normal. Certainly, the English firms rolling aluminium at high speeds have followed Transatlantic practice, whilst other large aluminium concerns here generally have kept to Continental practice and slow speeds. As may be noted, Britain has in the past adopted a middle position as regards rolling speed between the almost universal high speeds in the States and the slow speed usual on the Continent, but to-day there is here a tendency to favour America's high speed practice in almost all the strip rolling industries.

Lithium—An Alloying Element and De-Oxidising Agent

By STEPHEN COLEMAN.

ATTENTION is focused on untapped fields of employment for metallic lithium by the recent discovery of lithium ore desposits in Africa. Limitation of use for the metal has, up till recently, been caused by high price consequent upon complicated extraction and other concomitant factors. But German metallurgical interests, who have been engaged in research work for many years are possessed of new information regarding the metal's physical properties, and have evolved a method of extraction by which it can be produced and marketed at a price tremendously below that at one time ruling, and which was well above the quotation for gold.

The metal was first discovered in 1817, and mineral deposits containing it exist in many parts of the world. In Europe they are exploited in Saxony, in France and in the Pyrenees Peninsula, while in the United States large deposits containing lithium occur in South Dakota, Arizona and New Mexico. Deposits have also been found in the Canadian Provinces of Manitoba and Quebec, and quite recently in South West Africa and Rhodesia. From these territories bulk samples of ore have been sent to Germany for experimental purposes, and the result of investigations are destined to have a big influence on the future of the metal.

Ores and Constituents

There are four important ores of lithium from which the metal is extracted, but the percentage in them does not usually exceed about 4%. Amblygonite, an aluminium-lithium phosphate, found in America and Australia, sometimes carries about 8% lithium oxide ; spodumene, a lithium-aluminium silicate, occurring principally in America, Brazil and Sweden, contains about 3·8% lithium ; lepodolite, a lithium mica (found in Germany, Sweden, etc.) carries lithium ranging from 0·8 to 2·7% ; while triphyline, mined in America and Sweden, is a complex double phosphate containing sodium, iron and manganese, and about 3·6% of lithium.

In treating the mineral substance for the extraction of lithium, it is usual to employ a wet chemical process for the recovery of the lithium as carbonate. Other salts of lithium are prepared from the carbonate. The reduction of lithium salts to metal is accomplished by electrolysis of the fused chloride in the presence of potassium chloride, but other salts, such as the bromide, cyanide and hydride can be used.

Germany's Successful Researches

Much research work on lithium has taken place in Germany in the metallurgical laboratory of the Metallgesellschaft, at Frankfort.

It has been found by experiments that the addition of a few hundredths per cent. of lithium gives a degree of hardness to lead and aluminium and their alloys which could not be attained in any other way. A series of lead alloys have been discovered in which the added constituents is an alkali or alkaline earth metal or both, which can be used as efficient substitutes for lead-tin bearing metals. A small percentage of lithium added to lead alone hardens the lead sufficiently to form a good bearing metal. A lead alloy of this description, to which the name " Bahnmetall " has been given, is used in Germany on the State Railways, and has met with great success on account of its hardness, duration and unique physical properties.

Very small percentages of lithium also confer hardness and other good physical properties on aluminium. A good example of an aluminium alloy containing lithium is that known as " Scleron " used, in some cases, as a substitute for brass.

So successful have the Germans been with experiments on lithium that the Metallgesellschaft, after untiring laboratory work, have now erected equipment, on a large scale, for the manufacture of its own supplies of metallic lithium. They have a plant, probably the finest in the world, turning out large quantities of metallic lithium, and they supply not only their own needs, but also foreign call.

De-Oxidising and Purifying Agent

As lithium easily combines with the impurities of other metals, it is becoming more and more used in Germany for purifying other metals and improving their properties. Another interesting feature is that lithium, which itself melts at 180° C., forms an amalgam with mercury, which, in the combination LiHg, has a melting point of 609° C.

Mention must be made of the fact that the quantitative determination of lithium in an alloy containing only a few hundredths of the metal is exceedingly difficult, and this has been a very great hindrance to research.

In the United States, research is in progress in connection with the addition of small quantities of lithium to copper-wire bars. It is claimed that a small quantity of lithium greatly improves the surface properties of the copper. As a de-oxidising agent in the refining of copper, it has found a field of employment in America. In contrast to the phosphorus often employed for de-oxidation, lithium has the advantage of not appreciably reducing the electrical conductivity of the copper.

An alloy of extreme lightness, permanence and considerable hardness is being produced in America. It contains both lithium and beryllium—the latter metal protecting the lithium from oxidation by moisture or heat. Experiments taking place on it augur well for its extended use in many directions.

Other Physical Properties

It is lithium's natural tendency to oxidise, which has been such a teasing problem in research in Germany where the metal is packed in soldered air-tight tins. In consequence of its peculiar chemical and physical properties, it behaves totally different from every other metal. Other metals become covered with a layer of oxide which serves to protect them for a time from further chemical attack. But metallic lithium, the lightest of all solid bodies, having a specific gravity of 0·53, absorbs not only the oxygen, but also the nitrogen of the air, and form Li_2O and Li_3N, both of which are specifically heavier than the metal, consequently, inherent properties are lost, and the lithium is spoiled when this takes place. At a higher temperature it combines with hydrogen to form lithium hydride (LiH). It decomposes water at ordinary temperatures like sodium or potassium, and its capacity for taking up other elements is so great that in a molten condition it is able to abstract carbon, sulphur, phosphorus or occluded gases from alloys and metals.

Reviews of Current Literature

" International Control in the Non-Ferrous Metals "

Sponsored by the Bureau of International Research of Harvard University and Radcliffe College, this 800-page book has been compiled by a group of experts and economists dealing with all aspects of international control in the non-ferrous metal industries, excluding precious metals. It deals with tin, aluminium, copper, lead, nickel and zinc. Nickel, copper, lead and zinc are covered on the basis of historical outline, physical background, political implications and other pertinent data, by Alex. Skelton ; each of the latter three chapters being followed by a comprehensive review of the industry by Elizabeth S. May, and ample references are cited. Political implications are analysed by W. Y. Elliott, general economic aspects dealt with by J. W. F. Rowe, and the mechanics of international cartels is undertaken by Alex. Skelton.

Aluminium is reviewed by D. H. Wallace, treating of its technology and industrial structure, international control and agreements and the economic development and political influences from 1914 to 1933. A chapter on the international tin cartel is given by Elizabeth S. May, followed by a summary of tin investigation, international control of production, the tin Buffer Stock scheme agreement and the restriction quotas.

The following extracts serve to show the purpose of the work and the information it contains : " The Bureau determined to undertake a study of the efforts at international agreements among the producers of the non-ferrous metals, chief among them tin, copper, nickel, lead, zinc and aluminium. . . After a considerable exploration had been made of manganese, chromium, and the non-ferrous metals closely related to the iron and steel industry, it was decided that these metals did not afford typical cases of international control of the same nature as those chosen. Their relation to other industries complicated too many aspects of their control to make profitable their isolation. It ought to be added that the availability of research experts, especially competent from previous experience to treat particular ones of the non-ferrous metal industries, was a conclusive factor in undertaking the metals selected for study."

The cartel agreements among producers of the non-ferrous metals did not attempt to remedy those defects of the reaction from what had always been an imperfect system of *laissez-faire* international economics. Rather, accepting them as inevitable, the cartel tried to gain " all-round " reductions of production, with quotas based on immediate output, on the plea that the " common good of the industry " would result from preventing sacrifice dumping of stores on a sagging market. Mr. Elliott shows the illogicality of such an arrangement, and states that as a matter of fact, the international cartel of producers has in most instances broken down, in so far as it is a really international cartel, precisely under pressure from opposing factors. Ability to sell continued to be determined by cost of production, so far as there was a world market. Low prices rather than co-operative agreements appear to have produced shut-downs in most instances where international competition is possible. And when this became apparent, as it did in the copper agreements, the nationalistic tendency to insulate domestic from world prices produced the American copper tariff, and broke the world market into bits. Fluctuating foreign exchanges have helped this break-up ; but they were, after all, simply symbolic of the same factors of economic instability.

Capital still tends to be sufficiently international in character to make possible arrangements whereby no system can completely exclude the other. . . The rapid increase of " closed door " provisions, of tariffs, of discrimination against foreigners in mining and leasing, the beginning of concerted attempts to prevent foreign holding of resources within one's territory, may lead to a rapid breakdown of all international co-operation in industry.

The chapter on political implications covers such vital factors as the effects of nationality in the world metal industries ; the nature of state aid to national producers (with or without opposition to foreign reproducers) ; the effect of nationality in international organizations—in which Mr. Elliott shows that, although nationalism prevents the development of effective world cartels or of other organizations to relationalise the industry, the physical distribution of ore reserves has prevented any country from achieving complete economic self-sufficiency—and the political and economic aspects of " dumping " under conditions other than those of " distress selling " of surpluses.

Discussing general economic aspects, Mr. Rowe is of the opinion that experience to date points unmistakably to two tendencies or facts which are most disturbing in the light of our theoretical analysis. The first is that voluntary cartels will be formed in these non-ferrous metal industries as a remedy for conditions of excess capacity, even when general trade conditions are good, and that for a time such controls may well be successful in maintaining prices and preventing the amputation of the excess capacity, which may harm both producer and consumer by creating disequilibrium in the future, and the second conclusion from experience is that voluntary cartels are rarely capable of dealing with a severe trade depression, at least, in its initial stages, even when there is no superimposed problem of excess capacity . . . it is not usually until the depression has reached its most acute phase that voluntary cartels succeed in obtaining control of the situation, and then their policy is to raises prices very substantially, whereas the appropriate course at this phase is to encourage any incipient recovery of demand by lowering prices, or keeping them low, and not to take advantage of the improving demand to force prices up, which has been the aim of most control schemes in practice.

The mechanics of international cartels are dealt with by Alex. Skelton in an admirable chapter.

The history of nickel is traced back for more than 2,000 years, to its primary development in the Yunnan province in the south-west of China, where, too, zinc and copper abound, and were alloyed with the nickel to form a white copper alloy which eventually reached Europe. The occurrence of nickel, its production and marketing, are sections of considerable interest and are followed by a detailed survey of commercial history, completed by tables of nickel mine production, world production of refined nickel, nickel uses and consumption, and a series of charts and diagrams of the utmost value.

Aluminium, tin, copper, lead and zinc are treated in the same comprehensive manner, making a most interesting and informative book on a subject upon which too little is known and appreciated in the non-ferrous metal industries concerned.

By W. Y. Elliott, E. S. May, J. W. F. Rowe, A. Skelton, and D. H. Wallace ; published by Messrs. Macmillan and Co., Ltd., St. Martin Street, London, W.C. 2. Price 28s. net.

Research on Thin Layers of Tin

Following researches to compare the corrosion of tin with that of lead and of copper by oils, work has now been done to compare tin with iron and cadmium. Extremely thin films of the metals volatilised on to glass are used for the tests, and corrosion is estimated by the increase in translucence of the films. The degree of attack varied with the type of oil and the amount of water in it ; olive oil and earthnut salad oil were examined, in addition to lubricating oil. The results are published in a brochure, copies of which are available.

" Frostiness " in Plumbers' Solder

An investigation on the working properties of plumbers' solder having a frosty surface has just been carried out by the British Non-Ferrous Metals Research Association.

Because bad working properties and frostiness may both be produced by traces of impurity, frostiness has come to be considered an almost infallible indication of inferiority. Frostiness is, however, produced on good solder cast into an overheated mould, and is due in this case to the growth of large crystals. This report describes how solders were prepared with smooth and frosty surfaces and then used by practical plumbers. It is concluded that frostiness is not invariably a sign of poor solder.

Copies of the above publications may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

Principles of Powder Metallurgy

DURING recent years considerable significance has been attached to powder metallurgy, and this book, by Dr. W. D. Jones, supplies information on the principles and practice of this subject, dealing with the use of metal powders for forming solid articles by means of pressure and heat.

The cohesion that takes place when two metal surfaces are brought into contact is an action of the residual forces which lie at the surface. Although, as the author says, the concept of " cold " welding may be unfamiliar, there are, however, abundant examples. It has been shown that zinc globules will adhere to glass and steel, that there is strong cohesion between gold filings and glass, and there is the familiar example of the cold cohesion between block gauges.

The author sums up the basis of powder metallurgy by stating that it should now be satisfactorily established that two metal surfaces if sufficiently clean and sufficiently flat will weld or sinter together without the use of high temperatures. No work of this kind has been conducted at very low temperatures, but there is no reason to believe that any different conclusions would be obtained. It may well be asked, " Why, if welding can occur at any temperature, is it nevertheless usually practised at high temperatures ? " The conditions of commercial welding or sintering as far as temperature is concerned are purely a question of plasticity. No matter how well prepared, two metal surfaces cannot be flat from an atomic point of view. Pressed together, they will not touch atomically at all points. Naturally, a plastic metal under pressure will have a larger number of true contacts than a rigid one. The effect of increasing temperature is merely to increase the plasticity of the metals concerned.

It is suggested that the role played by recrystallisation is probably merely one of oxide removal, and the author shows that one may make the following conclusions :— (1) Effective forces involved in welding operations whilst varying with the nature of the metals concerned are mainly a matter of plasticity and, therefore, temperature and time. (2) Applied pressure taking advantage of plasticity increases the area of contact. How far pressure has an inherent effect in increasing adhesion is not known. (3) Area of contact is reduced by oxide films and the adhesional forces are diminished by certain gases and vapours. (4) Motion between surfaces in removing or puncturing surface films assists in increasing area of contact. (5) The mechanism by which recrystallisation modifies adhesion is not known.

But it is pointed out that there are at least eight variables which need consideration and investigation, answers being required for such questions as : (1) In what way do cohesional forces depend on plasticity and temperature ? (2) What is the relationship between cohesional forces and position in the periodic classification when comparisons are made, for example, at the characteristic temperature ? (3) What is the influence of time on adhesion ? Will time, as would be expected, be only important in the case of metals which flow plastically at the temperature of the experiment ? (4) Of what importance are oxide films and adsorbed gaseous films ? (5) What forces are necessary to rupture an oxide film and permit adhesion ? (6) What is the importance of pressure ? (7) What is the relation between bimetallic adhesion and chemical affinity ? (8 How does bimetallic cohesion vary with crystallographic orientation ?

This book deals with the principles of sintering, the influence of particle shape and size, the influence of applied pressure, the effect of temperature ; the volume effect, physical effect, and chemical effect of gases and vapours. After consideration of the physical properties of sintered metal compacts, including general characteristics, mechanical properties after cold compression and of hot-pressed powder compacts, and compacts of two or more metals, the many industrial applications are reviewed.

These applications include platinum, iron, nickel, nickel-iron alloys, bronzes (with special reference to porous, oil-impregnated bushings), tungsten and miscellaneous materials. The manufacture of hard metal alloys by both cold- and hot-pressing methods is discussed, and this is followed by a chapter which is a treatise on the manufacture properties and testing of metal powders. A very informative book, on a subject that has been needing authoritative treatment, and of interest not only to those engaged in the subject, but to the metallurgist of general interests.

By W. D. JONES, M.Eng., Ph.D. Published by Ed. Arnold and Co., 41-43, Maddox Street, London, W. 1. Price 15s. net.

Casting and Finishing Aluminium

A RECENTLY published foundry data book deals with copper and zinc alloys, with special reference to 3L5 alloy containing 13·5% zinc and 2·5% copper, and this is compared with straight copper alloys containing 6–8% copper ; silicon alloys and their characteristics and applications ; heat-treatable alloys, particularly " Y " alloy, and another simple heat-treatment alloy containing about 1·25% magnesium and 0·6% silicon with high resistance to corrosion and good anodising properties ; and piston alloys, showing the requirements demanded and the additions which make such alloys have characteristics nearer to the desired ideals of high strength and hardness at working temperatures with low thermal expansion. That interesting section is followed by useful tabulated matter relative to B.A. aluminium casting alloys and aluminium casting alloys to Air Ministry D.T.D. specifications. There is a most useful chapter on mixing of alloys, with valuable notes on how to make additions such as zinc, tin and magnesium, copper and nickel (including the making of both copper and nickel key metal).

Aluminium Finishing Processes

Another booklet on aluminium finishing processes is a logical companion to the foundry book. It is shown that the polishing of aluminium involves no radical departure from normal methods as applied to other metals, apart from the common-sense modifications entailed by the softer nature of aluminium. Types of abrasive and wheel speeds for roughing and buffing are suggested, this applying also to the handling of sheet metal at that stage, and the final polishing process of colouring by the use of a very soft wheel run dry with Vienna lime at high wheel speeds is mentioned.

Matt finished effects, such as frosting, scratch brushing, and sand-blasting are described, and have notes on procedure ; and this is followed by a section on the principles and processes of anodising. The M.B.V. process, by which the natural film of oxide on the surface of aluminium may be increased to provide improved resistance to chemical attack, is detailed, and the book is concluded by a chapter on painting and enamelling.

Copies can be obtained from the British Aluminium Co., Ltd., at Adelaide House, King William Street, London, E.C. 4.

Magnesite as a Refractory

IN our review of the above work by A. W. Comber, F.I.C., A.Inst.M.M., on page 202 of the last issue, we omitted to give the price. This book is published by Charles Griffin and Co. Ltd., 42, Drury Lane, London W.C.2., at 4s. net.

Cartelisation in the World Aluminium Industry* Part III

By Robert J Anderson, D.Sc.

The disparity between the extensive possibilities of production and the limited possibilities of consumption has long presented an economic problem, and the cartel movement is an effort to control producing and marketing activities. This article reviews the remaining part of the third international cartel, and indicates how rapidly the aluminium industry has progressed.

All Rights Reserved, including the right of translation into foreign languages.

THREE plants were built jointly by the Chemische Fabrik Griesheim-Elektron and the Metallbank- und Metallurgische Gesellschaft. The first came into operation in 1915 and the second and third in 1916. Of these, the first was closed at the end of the war, and the second in 1920; production has not been resumed. Metal is still being made at the third plant. In 1917 the Vereinigte Aluminium-Werke A.-G. was formed by the Chemische Fabrik Griesheim-Elektron, the Metallbank- und Metallurgische Gesellschaft, and the German Government. Construction of a large works was begun. In the same year the Erftwerk A.-G. was founded by Gebrüder Giulini G.m.b.H. and the Rheinisch-Westfälisches Elektricitätswerk in co-operation with the Government, and another aluminium plant was built. These latter two works were supplied with electric current generated by steam-power plants fired with lignite. Also, in 1917, the State of Bavaria, the German Government, the Allgemeine Elektricitätsgesellschaft, the Siemens-Schuckert Werke, and Gebrüder Giulini participated in founding the Innwerk A.-G. to build an hydro-electric power station and an aluminium works. Aluminium was first produced at this plant in 1925.

As a result of reorganisations subsequent to the war, the structure of the German aluminium industry has been considerably changed. Thus, the Griesheim-Elektron and Metallbank concerns reacquired control of one works on withdrawing from the Vereinigte Aluminium-Werke A.-G. in 1919. This plant is now operated by the Aluminiumwerk G.m.b.H., which is jointly owned by the Metallgesellschaft A.-G. and the I.G. Farbenindustrie A.-G. At the present time the hydro-electric power station of the Innwerk A.-G. is the property of the Vereinigte Industrie-Unternehmungen A.-G. and the State of Bavaria, while the Vereinigte Aluminium-Werke A.-G. controls the aluminium works. Finally, the latter concern is owned by the German Government through the Vereinigte Industrie-Unternehmungen A.-G., a holding company for governmental industrial enterprises. By 1926 Germany had advanced to second place among aluminium-producing countries.

The Elektricitätswerke Stern und Hafferl A.-G. started metal production in 1917 in Austria-Hungary; their plant is called the Aluminiumwerke Steeg.

In Italy a new aluminium works was completed in 1917: this is operated by the Società dell' Alluminio Italiano controlled by Aluminium, Ltd. Metal was produced temporarily during the War by the Società Idroelettrica di Villeneuve. An Italian works built by the Aluminium-Industrie A.-G. came into operation in 1928; the subsidiary company is called the Società Alluminio Veneto Anonima. Also, another plant was constructed in 1928 by the "Montecatini" Società Generale per l'Industria Mineraria ed Agricola Anonima in association with the Vereinigte Aluminium-Werke A.-G. The jointly owned operating company was named the Società Italiana dell'Alluminio. Production of aluminium in Spain was begun in 1927 by the Aluminio Español S.-A., now owned jointly by Aluminium-Industrie A.-G. and the Cie. de Produits Chimiques et Electrométallurgiques Alais, Froges et Camargue. A new works was built in Scotland by the British Aluminium Co. Ltd., and production was started in 1929 by an operating subsidiary firm called the North British Aluminium Co. Ltd.

In 1925 the name of the Northern Aluminium Co. Ltd. (of Canada), owned by the Aluminium Company of America, was changed to Aluminium Company of Canada, Ltd. In the following year construction of a new plant was begun in Canada. This was then planned as the largest aluminium-reduction works in the world. In 1928, Aluminium Ltd. was formed as a Canadian holding company and acquired all foreign assets of the Aluminium Company of America.

During the period 1915–1931 former members of the second cartel made additions to plants which were in operation before the War, and some of them built new works not mentioned in the above short statement. By 1929, total world capacity for aluminium output had been increased to approximately 300,000 tons a year.

Turning now to a consideration of the purpose for which the third cartel was organized, its objects were stated[4] to be the following (according to Article 1 of the agreement):—

"1. To regulate and control the aluminium sales of each of the members, more particularly by the exchange of commercial information in their possession.

"2. To promote, by all means and in conjunction with consumers, the more widespread use of aluminium.

"3. To supply the customers of every member with the quantities and qualities of metal requisite for his needs.

"4. To reduce to a minimum general costs and transport costs."

Control of sales was provided for on the basis of a quota apportioned to the members. The quotas applied to both the home and export markets, excluding North America. Provision was made for the examination, every three months, of the members' sales in order to effect any necessary equalisation between excess and deficient sales in respect of the quotas. This equalisation was accomplished by the transfer of metal at a determined price as between the members.

The agreement also specified that selling prices should be fixed with the object of maintaining uniform prices for all consumers in the various countries, regardless of transport costs. Thus, the cartel sought to establish a stable price structure for all countries within its sphere of influence. At the same time, it decided to reduce, rather than raise, prices. The members were given priority in their home markets, and selling prices in aluminium-producing countries were not affected by import duties. This applied to countries in Europe but not to the United States and Canada. In non-producing countries the selling price to the purchaser was the cartel price as fixed plus the import duty.

Other specific objects of the third cartel included the following: to increase output, expand exports to non-producing countries, exchange information in respect of technical processes and patents, eliminate competition and the transport of metal as between producing countries,

*Continued from January issue, page 90.

4 Benni, A. St. *et al.* "Review of the Economic Aspects of Several International Industrial Agreements, 1930." League of Nations Publ. No. E. 614. Geneva. 76 pp.

and promote co-operation among outside companies engaged in the production of semi-finished and finished manufactures. Thus, the aims of the organisation encompassed a range beyond that of the usual cartel.

In order to encourage the use of aluminium and its alloys as well as develop new applications the cartel established a joint advertising and research office at Paris. This was set up in 1927 under the name "Bureau International d'Etudes et de Propagande pour le Développement des Emplois de l'Aluminium," now called the Bureau International des Applications de l'Aluminium. This organisation collects and publishes information of interest to cartel members and also to consumers of aluminium, and convenes meetings of technical men representing the producers. It also arranges exhibits at trade fairs, holds prize competitions designed to find new uses, and otherwise endeavours to promote interest in aluminium.

The policy of the third international cartel was to reduce gradually the price of aluminium. When the cartel was formed, the price of 99% primary metal was £118 a ton. In September, 1926, the price was reduced to £105, and then in May, 1928, to £95, delivered, purchaser's works. The latter figure was maintained until October, 1930, when the price was fixed at £85. In Germany, the corresponding prices were, respectively, 2,360, 2,100, 1,900, and 1,700 marks a ton. For the six years 1926–1931, the average prices in the United States were as follows: 26·99, 25·4, 23·9, 23·9, 23·39, and 23·3 cents a pound. Comparison is made in later paragraphs of the prices for aluminium and other non-ferrous metals, as well as of their relative movements, over the 10-year period 1926–1935.

When first established, a principal object of the third cartel was to deal with the production and sale of primary metal, but its activities were subsequently extended to include some semi-finished manufactures. Thus, late in 1929, a pool of rolling mills in the cartel countries was organised to control the sale of aluminium sheet in British India and to eliminate competition there. The British Aluminium Co. Ltd. was appointed to handle sales in the Indian market for the joint account of the pool. Members of the syndicate participated in the total sales on a quota basis. It is also of interest to state that, in the same year, the cartel concluded an agreement covering the supply of aluminium to some Japanese consumers with the understanding that they would discontinue the purchase of American metal. Although not hitherto mentioned, it has been stated that one object of the third cartel was concerted competition against the Aluminium Company of America and its affiliated concerns. Among other indications the Japanese agreement, just referred to, has been offered as evidence of this intention.

Alliance Aluminium Cie., A.-G.

As mentioned above, the third international aluminium cartel was to have terminated, under the agreement, as of December 31, 1931. But in October of that year, a new organisation was formed to replace it. This was established in Basle, Switzerland as a stock company called the Alliance Aluminium Cie., A.-G. with a capital stock of 35 million Swiss francs. The stockholders in the new company included the members of the third cartel and also Aluminium Ltd. Thus, all important aluminium producers of the world, except the "Montecatini" Società Generale per l'Industria Mineraria ed Agricola Anonima, were represented directly or indirectly, as owners of the shares. The stocks of Aluminium Ltd., and the Aluminium Company of America are owned mostly by the same interests, and the floating supply of both is small. As is known, interference with market freedom and participation in cartels is prohibited by the anti-trust laws of the United States. The Montecatini concern concluded some agreements by which it was assured of placing output in excess of home sales. Also, in 1935, the Japan Aluminium Reduction Co. (see below) decided to co-operate with the cartel.

The Alliance Aluminium Cie. has continued to pursue the objects of the third international cartel, that is, to regulate output and sales, increase the demand for aluminium, and control the price. But the scope of the former organisation is broader and its influence is greater than in the case of the third cartel. Thus, one essential difference between the two has developed in that the Alliance Aluminium Cie. has engaged in various financial operations. For example, it undertook to finance stocks of aluminium pig during the recent industrial depression. This was done with the view to obviating price reductions by any distressed individual members as stocks increased and demand declined subsequent to 1930. Stocks of metal were financed in part by treasury funds and in part by bank loans. Also, in order to maintain the price and to prevent further accumulation of world stocks, which amounted to more than 300,000 tons at the end of 1931, output of the members was markedly restricted during the next two years. Metal stocks of the Alliance Aluminium Cie. were reduced substantially in 1932 by sales to the Soviet Union at appreciable reductions from the established price.

Late in 1931, the Alliance Aluminium Cie. acquired control of the Aluminium Corp. Ltd. and its subsidiary firm the International Aluminium Co. Ltd. And in May, 1933, the first mentioned company founded, in England, the Alliance Aluminium Holdings Ltd. with authorised capital of £400,000. Securities of the Aluminium Corp. Ltd. and the International Aluminium Co. Ltd., owned by the Alliance Aluminium Cie., were transferred to the Alliance Aluminium Holdings, Ltd. Thus, the latter is a sort of investment trust owned by the Alliance Aluminium Cie.

As indicative of other activities the Alliance Aluminium Cie. has been able to assure control of all important alumina plants in Europe, excluding those of the Soviet Union. In addition, efforts have been made to regulate output and sales of semi-finished and finished manufactures in both home and export markets, and to raise the prices of these products.

During the period 1932–1937 world capacity for aluminium output has been markedly increased as new producers have built plants and extensions have been made by some cartel members. Additional capacity has been projected. A brief statement regarding these developments of the last five years is relevant to the present discussion.

Striking achievements in aluminium production have been made since 1931 in Germany and the Soviet Union. Capacity of the Vereinigte Aluminium-Werke A.-G. has been substantially increased during the last three years, and German output in 1935 was the greatest of all countries. Capacity of the small plant owned by the Aluminium-Industrie A.-G. in Germany has also been enlarged. Production of aluminium has been stimulated lately by special circumstances. Lack of foreign exchange has restricted the purchase of copper and other imported metals, while governmental regulations have limited the use of various foreign commodities with the view to self-sufficiency. Then too, a methodical campaign has been carried on to convince engineers and the public that aluminium is "the German metal." As a result, the demand for aluminium has greatly increased. Present capacity in Germany is upwards of 100,000 tons a year, and it is thus second only to that of the United States.

After some years of planning and research, the production of aluminium was begun in 1932 on an industrial scale in the Soviet Union with the opening of the Volkhov works. This plant was originally designed, under the first Five-year Plan, for an annual output of about 6,000 tons. Enlargement of the capacity to 12,000 tons was projected under the second Five-year Plan (1933–1937). Production was started at a second plant, the Dnieper works, in 1933. This was designed for an initial capacity of about 20,000 tons a year; increase to 38,000 tons has subsequently been planned. The Volkov and Dnieper plants were built under direction of engineers in the employ of the Cie. de Produits Chimiques et Electrométallurgiques Alais,

Froges et Camargue. Construction was undertaken in 1933 of a third reduction works with a proposed capacity of 25,000 tons a year. This is referred to as the Kamensk works. And in 1934 construction was started on a fourth plant to have a capacity of about 10,000 tons. This is called the Kandalaksha works. Total capacity now built plus that planned to be in operation by the end of 1937 has been estimated by Soviet sources at about 85,000 tons. Output of primary aluminium by the Soviet Union in 1935 was 24,500 tons, and it ranked third among producing countries in that year.

Japan has been the scene of much activity in the field of aluminium production during the last few years. Two companies produced primary metal in 1934, the first year of recorded output. Companies which have recently undertaken to produce aluminium in Japan include the following: Japan Electric Industry Co., Sumitomo Aluminium Co., Japan-Manchuria Aluminium Co., Japan Aluminium Reduction Co., Japan Soda Co., and the Manchuria Light Metal Co. The first two started production in 1934, the third in 1935, and the fourth in 1936. Works are to be built by the last two. Total capacity intended to be in operation at the end of 1937 has been estimated at 23,000 tons. Additional capacity of about 50,000 is reported as projected. The Japan Aluminium Reduction Co. was organised in 1935 by the Mitsui, Mitsubishi, and Furukawa concerns together with the Government. As previously mentioned, it is allied with the international cartel. Japanese output of primary aluminium in 1935 was 4,700 tons.

Capacity for aluminium production in Italy has been approximately tripled since 1930. Extensions have been made by the Italian subsidiary company of Aluminium-Industrie A.-G. and by that of the Montecatini concern. The Società Italiana dell'Alluminio, owned jointly by the latter and the Vereinigte Aluminium-Werke A.-G., has been dissolved. A new company, the Società Nazionale dell'Alluminio, was founded in 1935 by the Montecatini concern to continue the production of aluminium. In the liquidation of the Società Italiana dell'Alluminio the German firm withdrew from participation and its holdings were acquired by the Montecatini interests.

(*To be continued.*)

United States Aluminium Industry in 1937

ALTHOUGH there was a sharp recession in business during the closing months of 1937, more aluminium was purchased in the United States during the year than ever before. This, according to H. A. Franke and C. T. Herring,* was due not only to the tremendous industrial demand earlier in the year, but to the discovery of new uses and the general broadening of sound and practical applications for aluminium. The service and performance rendered by aluminium emergency bulkheads constructed at the Gallipolis Dam on the Ohio River two years ago resulted in the application of similar bulkheads for the Emsworth Dam, north-west of Pittsburgh. Each aluminium bulkhead weighs only 15 tons, whereas a steel bulkhead, just two-thirds as high, would have weighed 28 tons. More buildings in Pittsburgh installed movable aluminium bulkheads, 12 feet in height, to serve as a protection against heavy floods.

The consumption of aluminium cable was the greatest in the history of the industry. To the 430,000 miles or more of aluminium cable, steel reinforced, already in use in the United States and Canada, additions included a 237-mile transmission line from Boulder Dam to the Colorado River Aqueduct and more than 100,000 miles of rural distribution lines. Aluminium cable is being used for a 230,000-volt line from Boulder Dam to Los Angeles, now under construction.

The transportation industry, which consumes 33% of the domestic aluminium output, found new uses for the light but strong metal. The order by the Interstate Commerce Commission permitting the construction of aluminium tank cars for transportation of aviation gasoline opens a new field hitherto inaccessible. It will probably be possible to transport other highly volatile chemicals in similar containers. Aluminium railroad passenger coaches, dining cars, kitchen-dormitory cars, and engine cabs are in operation. Fifty all-aluminium street cars are now under construction. Aluminium, long an important metal for the air, is still expanding its possibilities in the aviation field. Aluminium played a large part in the construction of the huge Boeing DC-4 and clipper ships, the 46-passenger Martin clipper built for Russia, and the army plane, Airacuda. In the marine field, a new aluminium mast was made for America's Cup boat, Ranger, and streamlined masts were used on iceboats. Twenty-two aluminium lifeboats, each seating 99 persons, were constructed in England for the Nieuw Amsterdam, flagship of the Holland-America Line. Each of three ferry boats to ply between New York and Staten Island used 55,000 lb. of aluminium for construction of shade decks and pilot houses.

Because of its high resistance to corrosion and lightness, aluminium is used for the manufacture of gratings and catwalks for sewage plants. More than 2,800 diffuser plate holders of aluminium were made for one of Cleveland's sewage disposal plants. A chemical plant installed four aluminium tanks, each of 80,000-gallon capacity.

Among the many newer uses for aluminium are listed aluminium as an ingredient in roofing material, aluminium windows and venetian blinds for the home and office, church steeples, statues and musical instruments. For the highway there are aluminium marker plates, automobile licence plates and headlight reflectors which give greater diffusion at the end of the highway beam, thus reducing glare for the approaching motorist.

A greater tonnage of new aluminium was produced during 1937 than in any other year. The 1937 record output of virgin aluminium amounted to 292,681,000 lb. valued at $55,609,000, compared with 224,929,000 lb. valued at $41,612,000 in 1936. Production in 1937 was 30% greater than in 1936 and exceeded the previous peak reached in 1930 by 28%.

The principal producing plant was that at Massena, New York, where approximately 37% of the metal made in the United States in 1937 was produced. The works at Alcoa, Tennessee, accounted for 31% of the output and the plants at Badin, North Carolina, and Niagara Falls, New York, contributed the remaining 32%.

Foreign trade in unmanufactured aluminium in 1937 showed a sharp increase in imports and exports. Imports of ingots, scrap and alloys rose from 25,158,541 lb. in 1936 to 44,701,669 lb. in 1937, and exports increased from 953,546 to 4,719,034 lb. Imports of sheets, tubes, utensils and other manufactured products increased in value from $1,108,630 in 1936 to $1,407,200 in 1937; exports advanced from $1,479,520 to $1,975,872. Foreign trade in manufactured aluminium is relatively small in comparison with the large domestic production and consumption.

The Aluminium Company of America started a $26,000,000 expansion programme in 1937, a large part of which will be completed in 1938. This will include the new alumina plant at Mobile, Alabama, a new extrusion mill at Lafayette, Indiana, a new sand foundry and forging plant at Los Angeles, California, and expansion of the large aluminium rolling mill at Edgewater, New Jersey. A longer period of time will be necessary to double the present capacity of the aluminium-reduction works at Alcoa, Tennessee.

*U.S.A. Bureau of Mines, Metal Economic Division, M.M.S 617.

"K" Monel Metal

MONEL metal has long been familiar to metal users as a reliable alloy possessing valuable properties. Its outstanding features are high resistance to corrosion and high tensile strength. It possesses great resistance to various corroding media, such as salt water, atmospheric attack, dilute acid, etc., and has the property of resisting to a very marked degree, the deterioration in strength to which the majority of non-ferrous metals are subject, from use at temperatures above the normal. Much research has been carried out to further improve the properties of this metal, and about three years ago a superior form of Monel metal was developed, which, after simple heat-treatment, possesses mechanical properties comparable with those of alloy steels. This alloy, obtained by the addition of aluminium and careful adjustment of the composition, is familiar as " K " Monel metal. One of the great advantages of this alloy is that it may be supplied in the soft condition and hardened after fabrication. It is readily workable either cold or hot. In the soft condition, it has a hardness of approximately 140/150 Brinell. By heat-treatment this hardness can be increased to 260 Brinell, while by a combination of cold work and heat-treatment, hardnesses of 320 Brinell or more can be obtained.

In the hot-rolled and softened condition, the tensile strength and yield-point of K Monel are 39 and 19 tons per sq. in. respectively. These values, by cold work and thermal hardening, can be raised to 72 and 60 tons per sq. in. No undue reduction of strength is found at elevated temperatures. At 540° C. the tensile strength of cold-drawn and heat-treated rod has been shown in short-time tests to be 55 tons per sq. in., with a yield-point of 45 tons per sq. in.

Applications

As may be inferred, the uses of K Monel are primarily those which require high strength and/or hardness, combined with good corrosion resistance and immunity from rusting.

In various services where unusually high mechanical properties combined with corrosion resistance are required K Monel shafts have given excellent service. For instance, this alloy has been adopted for marine pump shafts operating under severe mechanical stresses in continuous contact with salt water, and in this service has proved very successful. K Monel does not gall on Babbitt metal, as do certain other materials.

In Diesel engine-cooling systems, standard shafts of centrifugal pumps for circulating salt water are fitted with K Monel sleeves to provide greater hardness and strength to withstand abrasive conditions. Builders of locomotive boiler-feed pumps are now experimenting with shafts made from this alloy in order to obtain better service. A number of pumps have been fitted with shafts made from hot-rolled material, a collar at one end being formed by upset forging. All machining was carried out prior to heat-treatment. After heat-treating, the working surface of each shaft was ground off about 0·010 in. to remove the oxide and polish the working barrel. The tapers and threads were so slightly discoloured by the heat-treatment that it was possible to leave them in the " blued " condition.

A more recent application is in the rotor shafts of steam turbines. Forgings 5 ft. long and 4½ in. in diameter have been produced for use in marine steam turbines, driving close-coupled, salt-water circulating pumps. This application necessitates the following properties: High strength, stiffness, and torsional properties for transmitting power without vibration; hardness to resist abrasion and scoring; resistance to corrosion and pitting in salt water; galvanic neutrality when coupled with bronze pump bodies and bearings and cast Monel impellers mounted on the shafts; low heat transfer between cooling water contacted at one end of the shaft and superheated steam at the other; good bearing properties with Babbitt metal in hot turbines; low co-efficient of expansion for clearance in Babbitt bearings when cold, without danger of seizing at high operating heats. It is claimed this alloy affords all of these properties.

Valve manufacturers are increasingly specifying this metal, particularly for use in the oil industry. For example, for drop- and seat-valves used in certain oilfields where an exceptionally hard and strong material is required and corrosive conditions are such that iron-base alloys cannot endure. In one field, a K Monel drop-valve, after 14 months' service in oil-well pumping in contact with corrosive crudes, salt water, and hydrogen sulphide, is still in excellent condition, whereas steel valves were badly pitted after five days. To obtain higher mechanical properties without sacrifice of the corrosion resistance that they require, Diesel engine operators are making greater use of this material for seats and needles in fuel oil injection valves.

The uses of this metal have grown with greater knowledge of its properties, and it would be impossible to mention all its applications; it is noteworthy, however, that its non-magnetic and corrosion-resisting qualities in the fully hardened condition and at subnormal temperatures is utilised to considerable advantage in blind flying instruments, such as the Gyro-Horizon. This has also been responsible for its use as roller chain for retractable landing gear and controls of airplanes. While other successful applications include link studs, set-screws and machine screws, safety tools (non-sparking), ball bearings, lock washers, plungers in hydraulic shock-absorbers, electrical contact parts and needles for stretching woollens.

Elektron Magnesium Alloy

THE third edition of this book is now available. It has been compiled for the use of designers and engineers by a committee representing firms possessing many years' experience in the fabrication and use of Elektron alloys, such firms being the producers, suppliers and manufacturers of the Elektron alloys.

In the introductory chapter there is a brief account of how and why the magnesium alloys were developed, admittedly representing one of the most important achievements of recent years in practical metallurgy. In this chapter dealing with origin and development, the two commercial processes now employed for production of magnesium are described, these being the chloride process and the oxide process, the latter being used for the bulk of present-day production of the metal.

Both are electrolytic processes, the difference being in the raw material used. The chloride is based upon the use of carnallite (dehydrated), and the oxide process upon the use of a magnesium oxide ore obtained from the calcination of magnesium carbonate. This latter process has been developed to a high grade of technical efficiency during the past 20 years.

The history of the technical development of Elektron forms a most interesting section, and is followed by a few details of applications, particularly in the aircraft and transport industries. Three pages are devoted to definition of terms, with diagrams, and the main contents comprise sections on casting alloys (with advantages, specifications, mechanical and physical properties, with notes on machining and welding); wrought alloys (with notes also on welding and the working of sheet, plus a list of tubes, sheets, rods, bars and sections), surface protection; fire risks; and a very valuable section on the applications of cast and wrought Elektron alloys. The final section gives tables and comparisons that should be of great value to designers and users of the magnesium alloys.

The publication is indexed, well illustrated with diagrams and photographs, and contains much useful information in tabular form in addition to the sixth section which, as stated, is devoted to tables.

In view of the fact that the alloys are now being manufactured in Great Britain, and that they will soon be produced exclusively from raw materials available in this country, this book assumes an even greater significance, and can be recommended to our readers as giving the most up-to-date information regarding the application and use of magnesium alloys.

Published by Messrs. F. A. Hughes and Co., Ltd., Abbey House, Baker Street, London, N.W. 1, at 10s. 6d. net., who are the suppliers of Elektron magnesium-rich alloys and of magnesium metal for the British Empire.

Deep-Drawing and Pressing Problems

By J. D. JEVONS, Ph.D., A.I.C.

The industrial processes by which sheet metal is formed into shape were discussed by the author recently before the Midland Metallurgical Societies, in which he considered operations on both ferrous and non-ferrous sheet. In this abstract attention is directed mainly to the drawing and pressing of brass sheet.

THE term " deep drawing " is generally applied when sheet is shaped in a press, to distinguish it from the forming operation of drawing wire from a rod. Usually the process starts with a circle cut from sheet of the proper thickness. A plunger pushes the centre of the circle downwards into or through a die. The metal circle is thus subjected to tension radically and compression tangentially. A blank of soft sheet metal is placed on a die or draw ring having a smooth top surface, which may be flat, as shown in Fig. 1, conical or of curved contour. This die contains a hole of a shape which corresponds to that of the article it is desired to produce, the edge of the hole is radiused, and the dimensions of this radius relative to the thickness of the metal being shaped are of considerable importance. The more smoothly polished this radius is the better, and irregularities tend to produce at least three undesirable happenings—they tend to rupture the film of lubricant which is supposed, and supposed is said advisedly, to prevent actual metal-to-metal contact between the die and the sheet sliding over it ; they tend to score the surface of the sheet, and, lastly, they tend to hinder the flow of the metal, thus increasing the stress in the walls of the drawn portion of a shell and making failure more likely.

A punch having a cross-sectional outline of similar shape to that of the hole in the die, but of slightly smaller area, and having its axis normal to, and accurately centred in, the die, is then forced down into the hole in this latter. If all goes well, the metal sheet flows over the die radius and follows the punch in the desired manner. If this does not happen, one of the deep-drawing problems implied by the title of this paper arises and demands solution.

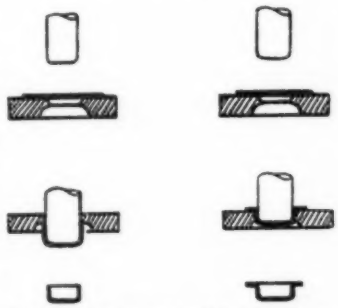


Fig. 1.—Two operations in deep drawing.

Notice that the punch may push the blank right through the die, as shown on the left of Fig. 1, or, as shown on the right, it may descend to a pre-determined depth which will leave some of the blank in its original plane above the die, but, of course, thickened considerably, due to the contraction its periphery will have suffered. This arrangement works quite well if the guage of the sheet is fairly heavy in relation to the size of the article being formed, because the crowding-up which occurs as the periphery of the blank gradually becomes smaller manifests as a *uniform* increase in thickness. When, however, thin sheet is used, the tendency is for the metal which has not yet flowed over the radius of the die to wrinkle up into a series of waves, instead of increasing in thickness uniformly.

To prevent this undesirable occurrence, it is customary to load the upper surface of the blank with what is known as a " pressure-plate " or " blank-holder," as indicated on the right of Fig. 2. The purpose of this plate is to press the blank into contact with the top face of the die with a force such that it will not seriously hinder the flow of metal, but will nevertheless cause the blank to thicken uniformly and prevent it wrinkling. This brings the first problem—namely, how to exert exactly the desired pressure on the blank-holder.

As the blank thickens during its progress over the face of the die before flowing over the radius, it is obvious that the pressure-plate cannot be mounted rigidly, and in the past it has been customary to arrange for it to slide on, and be located by, pillars and to be loaded by spring pressure. More recently, pneumatic rams or " cushions," often without the assistance of springs, have been used to exert force upon the pressure plate. Still more recently, hydraulic loading has been used. The advantages of these newer methods of operation are, first, that they enable the force to be varied more quickly and more accurately than is possible with springs, and, secondly, that with them it is possible to arrange for the load on the pressure-plate to be decreased during the actual stroke of the press by automatic means. This is of genuine help, for if a recording manometer be attached to a pressure plate the record traced as the draw proceeds will be of a shape something like that shown in Fig. 3. Clearly, if the loading on the plate remains constant, the blank will be loaded unduly heavily during the final stages of the draw.

Wrinkling of a blank is generally a defect to be prevented, but because the effect is usually surprisingly

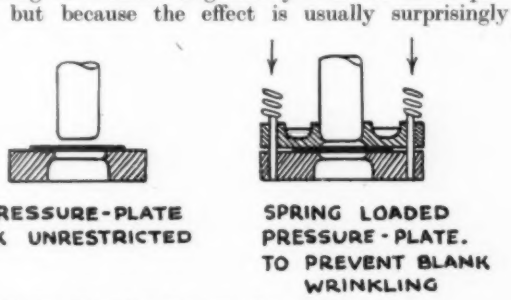


Fig. 2.—Showing the use of a pressure plate.

regular, it can occasionally be utilised for decorative purposes, apart from which it is occasionally encouraged for some genuine utilitarian purpose, as, for example, in the rim of the metal shell of the Crown corks which are now used to seal so many kinds of bottles.

As regards the terms " deep drawing " and " pressing," it has been the author's experience that they are confused on all occasions, even by industrialists of long experience. The author likes to think of operations such as that shown on the left of Fig. 4 as " pressing," the essential point being that there is clearance between the metal and the tools, and that the metal is, therefore, thinned only by reason of such elongation as it may suffer due to the action of tensile stress. It is suggested that the term " drawing " should be reserved for the condition depicted on the right of this illustration in which the space between the tools is *less* than the thickness of the metal entering this space and the metal is thinned not by a pure tensile stress but by definite mechanical pressure. This process is known technically as " ironing," and is akin to the actual " drawing " suffered by a tube which, supported by a mandrel or plug, is drawn through a die.

Metallurgical Problems

The metallurgical problems of drawing and pressing both for steel and brass sheet fall into three categories. These

are—the problem of testing sheet metal, problems attributable to defects in purchased sheet, and problems which arise through the treatment given to purchased sheet by the user when he presses and draws it.

Referring to defects in brass sheet, the first to be considered is inclusions. Fortunately, the presence of seriously injurious inclusions in brass sheet is very rare ; there is no direct parallel to the pipe and non-metallic inclusion type of defect which is so common in steel. The chemical composition of brass sheet, unlike that of steel, causes trouble occasionally. In these days it is rare for the copper content to fall below the specified minimum value, and still rarer for the proportion of harmful impurities, such as cadmium or tin, to rise to a dangerous value through the use of contaminated scrap. Iron sometimes rises to a proportion which, though not sufficiently high to cause a really serious reduction in ductility, renders the behaviour of the metal erratic during annealing. Small amounts of phosphorus of the order of 0·004% are sometimes added to retard crystal growth during annealing, and quite recently it has been shown by two American workers that a small proportion of chromium is far more effective than phosphorus in achieving this end. If the proportion of these added elements is inadvertently increased beyond the very small values which are desired, the ductility of the sheet becomes seriously impaired.

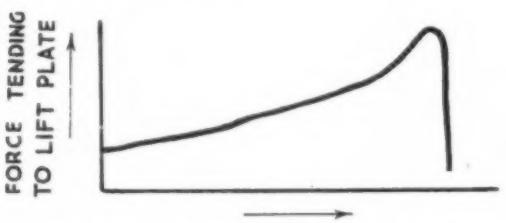


Fig. 3.

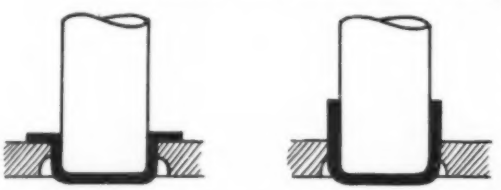


Fig. 4.—Distinguishing between deep drawing and dressing.

Lead is an addition, rather than impurity. Its effect upon deep-drawing and pressing properties is determined mainly by the state in which it exists. Using special means to ensure the dissemination of lead throughout the crystal structure in very small, isolated globules, our American friends are now successfully pressing and drawing brass to which about 2% of lead has been added to facilitate subsequent machining operations. Needless to say, any agglomeration of these very fine globules renders brass of this composition unsuitable for pressing or drawing.

Free beta constituent is often found in commercial quality brass sheet containing 63 to 64% of copper, and sometimes in brasses of higher copper content. The author's views on the subject of beta have been considered a little exaggerated, but he can give an assurance that the presence of a considerable proportion of beta does seriously impair the deep-drawing and pressing properties of ordinary alpha-brass sheet. It is submitted that there is ample proof that the presence of an appreciable proportion of beta constituent *does* reduce the ductility of brass sheet, and that for this reason users are bound to regard it as a defect, often of a serious nature.

The crystal structure of a large proportion of industrial brass sheet can only be described as unsatisfactory from the particular aspect of deep drawing and pressing, indeed it is very rarely that one sees a sample of brass which possesses what the user calls a good crystal structure. There are two defects—the size of the crystals is highly irregular, that is, in any given area, small and large crystals exist side by side, and the " average " grain size, a value which, due to the wide range of size usually present, may be difficult to estimate, and then only partially informative, is seldom constant or within the range for which the user has asked. Admittedly, some of the effects attributable respectively to large and small crystals cancel out to a limited extent, but in an aggregate the tiny crystals reduce the ductility well below the normal value for the adjudged " average " crystal size, while the large crystals tend to produce a surface nearly as rough as that given by an aggregate of uniformly large crystals. A very common defect is the occurrence of stringers and planes containing crystals of very small size. Usually, but not always, the regions of tiny crystals contain beta phase, a fact which still further impairs their ductility.

There is another point relating to crystal structure. It is established as a recognised fact that, after pressing, a sheet having a large crystal size—say, of the order of 0·10 to 0·20 mm.—will produce a very rough surface in comparison with the surface given by metal of, say, 0·03 to 0·05 mm. average grain size. It is said that this roughening is due to the slipping and rotation of the crystal grains, but surely the order of roughness is far greater than this unqualified explanation can account for. What we may describe as a single undulation in a so-called " orange-peel " surface must embody very many crystals, and it seems as if a kind of block movement, in which blocks or aggregates of many crystals slip and rotate in a manner similar to that observed in a single crystal, must take place. An internal block or mosaic structure is, of course, known to exist within the crystal itself, and it seems likely that the phenomenon is repeated on a larger scale.

Directional properties in brass sheet tend to be less pronounced, and therefore less harmful, than in steel. It is of interest to notice that the direction of minimum ductility lies at 45° to that of rolling in nearly all commercial brass sheet, although other directions have been obtained after special rolling. It will be recalled that in steel, 0° and 90° are the favoured directions of minimum ductility. Apart from effects attributable solely to crystal structure, stringers of small crystals give directional tendencies comparable to those given by strings of non-metallic inclusions and planes of segregation in steel.

Surface defects also tend to be less serious in brass than in steel, and certainly less prevalent than of old. This may be due in some measure to the increasing tendency to machine the surface of ingots and partly-rolled slabs. The surface finish on a fair proportion of commercial brass sheet is excellent, and often better than the user can take full advantage of.

Regularity of thickness is much better with brass than with steel, due partly to the greater ease with which brass can be rolled and partly to the fact that the width of the sheets normally used are considerably less than in the case of steel. The user would, however, welcome less variation in the thickness of the wider strip in some instances.

One name which has been associated with specialisation in the production of nickel alloys for the last hundred years is that of Henry Wiggin and Co. Ltd. This company has now produced an 8-page booklet giving a complete list of those metals which they manufacture and/or sell.

In this list each product is named, the form in which it is usually supplied, its composition and general notes on its application are given. In addition to fourteen nickel products there are also details of Monel metal, various nickel-silver alloys, thermo-metal, alloys for re-melting, metals for turbine blading and accessories, cobalt oxides, cobalt salts, nickel oxides and salts, selenium, ferro-selenium and tellurium.

The booklet is completed by two pages of purposes for which these products are recommended, tabulated under the headings of " Industry," " Application," and " Material."

Copies can be obtained from the manufacturers at Thames House, Millbank, London, S.W. 1.

Steels and their Utilisation for High Steam Pressures and Temperatures

By R. W. Bailey, D.Sc.

The most important aspects of the metals and parts for high steam temperatures in connection with land power plant were outlined by Dr. Bailey in a recent paper before the Institute of Marine Engineers with a view to giving confidence to marine engineers considering the possibilities of higher steam pressures and temperatures for ship propulsion. In this article a brief abstract is given.

ALTHOUGH steam pressures exceeding 1,000 lb./in.^{2} have been used successfully on land for a number of years, and steam temperatures of 850 to 875° F. have been fairly common, it is perhaps unlikely that in marine practice pressures much exceeding 500 lb./in.^{2} and temperatures exceeding 850° F. are expected to any extent for some time. Generally these conditions can be met successfully by the use of carbon steels for most parts, and only in a few special applications, such as bolts for joints under pressure, need special steels be considered. It is a mistake therefore, to think that carbon steels are not suitable for elevated temperatures. Actually they may be the most suitable steels if working stresses permit their use. Examples could be given of the use of carbon steel for highly important parts operating at temperatures of 900° F. and over. It is therefore, necessary to know with some completeness and precision the behaviour of carbon steel at elevated temperatures. It happens that the behaviour of carbon steels affords a good introduction to other steels of superior strength and endurance.

Long exposure of carbon steel to high temperature results in two effects, one due to temperature and the other due to stress. The former causes a change in structure and also to some extent a reduction in strength ; and the latter results in continued permanent deformation or creep. Structural change is common in superheater tubes for example, for quite moderate steam temperature, and would therefore not be new in marine engineering experience. It would become more pronounced, of course, with the use of higher temperatures, but it would not result in any unreliability. Similarly creep, if kept within appropriate limits by a proper choice of working stress, involves no risk. Indeed its presence in many cases is a distinct advantage because it leads to a more suitable distribution of stress and therefore actually facilitates the use of high pressures.

Although considerable data exist upon the creep behaviour of carbon steels, very little of it is directly applicable to design. Also the effect of carbon content upon creep resistance is still doubtful, although apparently it is not very important.

Permissible Deformation and Working Stress

Working stress must of course, depend upon the amount of deformation one is prepared to permit during the life of a part. If the life is taken as 100,000 hours (11·4 years continuous) a total strain of 0·001 in. per inch is satisfactory for all parts (except press fits) where very small creep is essential. For tubes and pipes as much as 0.003 strain and more could be allowed with carbon steel, although because of a need for some margin a greater amount than 0·003 strain would not be advocated.

Alloy Steels

Investigation and land practice have established that when a steel more resistant to creep than carbon steel is required this is best provided by a carbon molybdenum steel. The addition of molybdenum to a carbon steel increases the creep resistance in a marked degree. Improvement is obtained with additions up to 1 to 2% molybdenum but something like 70 to 80% of the maximum obtainable results from an addition of only 0·5% molybdenum. Consequently, 0·5% molybdenum steels have come largely into use for high-temperature service. As normalised they have a creep resistance usually two to three times that of the corresponding carbon steel and consequently where really high pressures are combined with high temperatures they become essential. Experience has shown that they are reliable steels in all the usual forms such as castings, forgings, pipes and tubes.

Reference should be made to the mode of failure under creep of 0·5% molybdenum steel, which is characteristic of probably all high creep resistant steels. In investigating molybdenum steels Jenkins and Tapsell of the National Physical Laboratory discovered that extensive intercrystalline cracking occurred under creep conditions, the commencement being observable at relatively small elongation of the order of 1·5 to 2%. All steels of high creep resistance of which the author has had experience fail by intercrystalline fracture with low ductility. Failure over a wide range of temperature and stress, is determined very largely by the magnitude of the deformation. Since there is a possibility of fracture taking place at elongations as low as 3 or 4% and the microscope reveals the commencement of intercrystalline cracking at elongations of 1 to 2%, it is clearly necessary in practice to limit deformations by creep to less than 1%. For this reason the author would advise that a total creep of 0·003 in. per inch for the life of the plant should not be exceeded and if circumstances permit, it should preferably be less, a good figure being 0·001 in. per inch. From the standpoint of actual failure carbon steels could safely be permitted ten or more times the deformation allowable for the corresponding 0·5% molybdenum steel. Such large safe deformations in the case of carbon steels, would of course, be inadmissible on account of the dimensional changes involved. Comparing carbon steels and corresponding molybdenum and other high creep resistant steels, the permissible creep is determined in the former case by dimensional considerations, and in the latter it is set by intercrystalline cracking independently of the nature of the part.

At present, suppression of intercrystalline cracking under creep of high creep resistant steels appears to be a problem which may prove fundamental in character and inherently associated with high creep resistance. Its elimination at present therefore does not appear to be very hopeful. If elongation at failure could be increased however it would be an advantage.

Land experience and investigation has served to reduce alloy steels most suitable for high steam temperatures to one or two steels. Methods of short time creep tests, used extensively on the Continent and to some extent in the U.S.A. have suggested a general superiority of a chromium molybdenum steel, having about 1% chromium and 0·5% molybdenum steel. This is only true within certain limits of temperature and time. It is in fact, an example of a general principle affecting the creep properties and utilisation of alloy steels. The addition of an alloy element to a steel will generally have two effects, namely, it alters (1) the initial creep resistance, (2) the eventual effect of temperature in weakening creep resistance. If

an element increases the initial creep resistance and also if it brings about a more rapid weakening under thermal action, the result will be as follows. Below a certain temperature the initial stiffening effect will preponderate over the thermal weakening and the addition of the element confers advantage. Above that temperature the initial stiffening would in time be more than offset by the weakening by thermal action, and the alloy addition would therefore in this case be a disadvantage. Evidently from this standpoint, length of service is also a factor influencing the temperature where the changeover occurs, and without reference to both operating temperature and life, no general statement can be made regarding the superiority of one steel over another.

The place taken by nickel in low-alloy steels for elevated temperatures is of interest. Its first use, where creep was recognised as important, was in nickel chromium molybdenum steels for joint bolts. Investigation showed such steels to have good creep resistance at temperatures up to about 450° C. (842° F.) but in the region of this temperature the stress for a given creep rate fell rapidly with increase in temperature. It was suspected that nickel was responsible for this falling away, due to the influence of this element in increasing the rate of weakening, under thermal action. Creep tests upon chromium molybdenum steels and nickel chromium molybdenum steels of similar chromium and molybdenum contents, confirmed this suspicion and showed that omitting the nickel gave improved creep resistance, and at the same time resulted in a steel free from embrittlement in service as shown by the Izod impact test at atmospheric temperature. To-day, therefore, for temperatures where creep is important, nickel chromium molybdenum steels can be regarded as superseded by chromium molybdenum steels which are generally superior and cheaper. The author also investigated the influence of nickel up to 3% upon a 0·5% molybdenum steel. In all cases a reduction in creep resistance occurred with the addition of nickel. This reduction, however, was not large, and as the Brinell hardness increased regularly with the nickel percentage from 150 to 210 Brinell for 3% of nickel, or an increase in ultimate tensile strength of probably 13 tons/in.² a nickel molybdenum steel would appear to be a possible steel for steam drums and like parts where temperatures are not so high that creep would entirely dominate the selection of working stress. It is possible that for such a steel a case could be made, in the direction suggested, for temperatures up to about 850° F.

Shaft Sinking at Falconbridge Mines

A SHAFT-SINKING job through a 100-ft. layer of overburden at the Falconbridge nickel property, regarded in mining circles as somewhat of an engineering feat, was described recently to members of the Canadian Institute of Mining and Metallurgy by Mr. R. M. Oliver, the company's chief mine engineer. Consisting of gravel, sand and boulder, with bands of very fine silt, the overburden usually is found to contain a layer of water-bearing quicksand adjoining the rock surface, which in previous shafts sunk at Falconbridge had given considerable trouble. The method of sinking through this overburden is one adopted after several plans had been considered.

Sinking proceeded with a shaft crew of seven men and a leader by digging inside of a steel shield which was jacked down as the work advanced one man being stationed at each corner during jacking to keep the shield level. Sand was prevented from running in at the corners by plugging with burlap. Working three eight-hour shifts an advance of approximately 6 ft. a day was made.

Chief difficulty was encountered at a depth of about 100 ft., where, after sinking through a 3½-ft. ledge it was found that the shart had hit a knoll and that the bedrock fell away very steeply on one side, and was almost a sheer cliff on one corner. Dowel holes were drilled, and a 20-in. wall of concrete was poured inside the shield to a height of 5 ft. around the portion of the shaft down to the rock.

Corrosion of Alloys by Solutions

WHILE corrosion problems dealing with aqueous solutions have been the subject of extensive investigations, little effort has been made to extend such studies to non-aqueous solutions. The Haber synthetic ammonia process has made available to industry a solvent which can be produced in large quantities at a low cost, and liquid ammonia has become one of the cheapest anhydrous solvents on the market. Liquid ammonia rivals water in its ability to take into solution inorganic compounds and it is far superior to water as a solvent for organic compounds. Ammonia salts, when dissolved in ammonia, act as acids, and as such solutions have already found use in a number of processes which have assumed technical significance, it is obvious that the corrosive effect of such solutions is a factor of distinct importance to industry.

A survey of the available information dealing with the action of ammonia salts in liquid ammonia upon metals reveals the fact that such data is not only fragmentary, but very qualitative in nature; and that no data on the resistance of alloys has been made available to date. The results, therefore, of a preliminary investigation, which has has been carried out by L. F. Audrieth and T. E. Franks[1], for the purpose of determining the resistance of some of commoner alloy materials to liquid ammonia solutions of ammonium chloride, ammonium nitrate, and ammonium thiocyanate, is of value.

The corrosion tests were carried out at room temperature on weighed, ground samples, placed in separate sealed glass tubes. All the tubes were calibrated to contain 15 ml. of solution and 1 grm. of ammonium salt was used in each case to give solutions of comparable concentration, and after the alloy specimens and ammonium salt had been placed in the tubes, the latter were cooled in a solid carbon dioxide-acetone bath and liquid ammonia added to give the proper volume of solution. The tubes were then sealed and allowed to stand for three months, with occasional examinations for evidences of chemical action, after which the tubes were opened, the solutions evaporated, and the alloy specimens cleaned, dried, and weighed and the loss in weight per sq. centimetre calculated.

The results of the tests indicate that chrome-nickel steels and high chromium steels are quite resistant to corrosion by solutions of both ammonium chloride and ammonium nitrate and that it is the addition of chromium which produces this resistance, as various samples of iron and steel subjected to the same tests undergo appreciable attack. The same iron alloys, however, are readily attacked by solutions of ammonium thiocyanate. The copper alloys, which included brasses, bronzes, and cupro-nickel alloys, were readily attacked by all these solutions, and solutions in contact with the various copper alloys invariably assumed the characteristic blue colouration leading to the assumption that corrosion involves at least partial solution of the copper in the cupric state. The corrosion of chemical lead serves to illustrate the difference between aqueous and liquid ammonia solutions of acids. At ordinary temperature dilute hydrochloric acid attacks lead slowly, while corrosion by ammonium chloride in liquid ammonium is very marked. The addition of 6% of antimony to lead increases materially its resistance to the ammonium chloride solution. Nickel, wrought iron, and steel suffer appreciable attack by solutions of all three ammonium salts. Aluminium is not attacked by ammonium nitrate solution in liquid ammonium, which is presumably due to the fact that the oxide film on the metal is not dissolved or removed.

Mr. Charles S. Gill, previously commercial manager of the Davy and United Engineering Co., Ltd., has now been appointed director and general manager of Davy and United Roll Foundry, Ltd.

1 *Metals and Alloys*, 1938 Vol. 9, No. 2, pages 51 and 52.

Business Notes and News

Darwins-Toledo Merger

The acquisition of the old-established Sheffield steel firm of Andrews Toledo Ltd., by Darwins Ltd., also of Sheffield is officially announced. Although in future the two businesses will be conducted by a single board of directors, each business will maintain its separate identity, and the trade marks, and manufacturing processes of each business will be retained by each.

In connection with the completion of the merger it is announced that Mr. A. P. Good, a director of Andrews Toledo, has been nominated to the board of Darwins Ltd., while Mr. W. H. Thomas, who has been managing director of Andrews Toledo, has been elected technical adviser to the combined undertaking of which Mr. H. L. Armstrong is chairman and Mr. W. J. Wigney, managing director.

The total assets of the combined business are now over £676,000. For Andrews Toledo the purchase price, now paid over, was £270,000, satisfied as to £50,000 in cash, £25,000 in 5% debenture stock of Darwins Ltd., and £195,000 in 10s. ordinary shares of Darwins Ltd. Recently it was announced that a £100,000 issue of 5% debenture stock made by Darwins Ltd., in connection with the merger was fully subscribed by shareholders.

An extensive modernisation scheme, involving the erection of a large and newly equipped heat-treatment shop, and the creation of more commodious storage room for raw materials, has been begun at the works of Andrews Toledo, Ltd., the Sheffield makers of specialised steels. The new development is part of a general plan for speeding up output of heat-treated steels used in aircraft manufacture and other engineering work, following the amalgamation.

A Steel-making Record

The latest 300-ton tilting furnace installed at the Appleby-Frodingham Steel Co., Ltd., Scunthorpe, Lincolnshire, an associate company of The United Steel Companies, Ltd., has created what is believed to be a record for Great Britain for the output of one steel furnace in one week. It produced 2,800 tons of steel ingots during the week ending March 26.

New Iron and Steel Plants for U.S.S.R.

Six new blast furnaces, with an aggregate output capacity of 2,620,000 tons of pig iron a year, and 11 open-hearth furnaces, with an aggregate capacity of 1,391,000 tons of steel, will be put into operation at the iron and steel works of the U.S.S.R. in 1938. At the Stalin Works, in Magnitogorsk, four open-hearth furnaces, each with a capacity of 160,000 tons, will be put into operation, while the rolling mill shop of this works will acquire an additional blooming mill designed for an annual output of 1,600,000 tons of blooms, and a wire-drawing mill capable of turning out 270,000 tons of wire a year.

Two blast furnaces, will shortly be blown in at the Novo-Tagil Works each with an annual output capacity of 360,000 tons of pig iron, while in the open-hearth shop two new open-hearth furnaces are in course of erection.

At the Zaporozhatal Works a continuous rolling mill for hot and cold rolling will be put into operation in the near future. This mill is designed for an annual output of 900,000 tons of thin sheets. At the same works three open-hearth furnaces are in course of erection, which are expected to be operation in the third quarter of the year. The output capacity of each furnace is stated to be 150,000 tons a year. Installations at these works include No. 3 blast furnace.

Further installations at the Krivoy Rog Works include a blast furnace with a volume of 1,300 cub. m. and a capacity of 560,000 tons of pig iron a year, also two Bessemer converters, each capable of producing 500,000 tons of steel per year. A further blast furnace will shortly be blown in at the Azovstal Works, while an additional one is being built for putting into operation later in the year. At the Makeyevka Works a wire drawing mill is being installed, which will produce 270,000 tons of wire a year.

Lincoln Gold Medal

A Board of Awards, composed of H. L. Whittemore, chairman, and Messrs. G. T. Horton and A. G. Oehler, was appointed in January by the Executive Committee of the American Welding Society, to have charge of selecting the recipient of the Lincoln Gold Medal for 1938. Following appointment, the Board drafted regulations governing award of the medal which has been accepted by the Society for annual award.

Notched Bar Testing

In October last a conference on notched bar impact testing, which was originally arranged by the Joint Committee on Materials and Their Testing, was held in Manchester. All the papers presented can be obtained as abstracts from the Transactions of the Manchester Association of Engineers, which was responsible for the local arrangements for the conference.

The papers presented and dealt with in the book are of an international character, prepared by such authorities as: Dr.-Ing Max Moser, of Krupps, Essen; one by Captain R. K. Haskell and H. C. Mann, of the Ordnance Department of the United States; and the others by Professor Southwell, of Oxford, and Mr. L. W. Schuster, of the British Engine and Boiler Insurance Co., Manchester. The book is obtainable from the Manchester Association of Engineers, St. John's Chambers, Manchester.

Crossing the Atlantic by Steam Power

This month celebrates the centenary of the crossing of the Atlantic solely by steam power. Several vessels had made the crossing earlier by means of sails and steam, such as the Dutch vessel *Curacao*, which was built at Dover in 1826, the *Royal William*, built at Quebec in 1831, and the American ship *Savannah*, which crossed from the United States to this country in 1819, but the honour of crossing under steam alone belongs to the paddle vessel *Sirius*, which set out from Cork on the morning of April 4, 1838, and made the passage in 18 days.

Two companies were formed, by men of foresight, to build vessels specially for the Atlantic crossing. These were the British and American Steamship Co. and the Great Western Steamship Co., and keels for the *British Queen* and the *Great Western* were laid in 1837 by the respective companies. Those responsible for the engines for the *British Queen* failed, and the vessel was not completed until long after the *Great Western*. The British and American Steamship Co., however, were determined to be first to complete the crossing under steam, and chartered the *Sirius* from the St. George Steam Packet Co., of Cork, to make the passage.

The *Sirius* was a coasting vessel, and certainly not built for such an arduous undertaking. She was built at Leith, and engined by a Glasgow firm. Her net tonnage was 412 tons, with a length of 178 ft. On her historic voyage, under the command of Lieut. R. Roberts, R.N., she carried a crew of 38 and 40 passengers. More than once on the voyage the crew were on the verge of mutiny, and the passengers many times implored the commander to turn back. She arrived in New York about eleven hours before the *Great Western*, which had made a faster crossing, and caused the achievement of the latter to lose much of its significance.

Personal

Mr. Alexander Williamson, general manager of the Steel, Peech and Tozer branch of the United Steel Companies, Ltd., and Master Cutler in 1934, has been appointed managing director of William Beardmore and Co., Ltd., Glasgow.

Mr. H. H. Burton, who succeeded the late Mr. J. H. S. Dickenson as chief metallurgist of the English Steel Corporation, Ltd., in January, 1935, has been appointed a special director of the company.

Dr. Robert Hunter has been appointed a director of the Clyde Alloy Steel Co., Ltd., the special steel subsidiary of Colvilles, Ltd. He has been chief metallurgist of the company for some years.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£81	10	0
Chinese		67	0	0
Crude		40	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11
Brazed Tubes	,,	0	1	1
Rods Drawn	,,	0	0	8½
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	5

COPPER.

Standard Cash		£38	10	0
Electrolytic		43	0	0
Best Selected		42	5	0
Tough		41	15	0
Sheets		73	0	0
Wire Bars		43	10	0
Ingot Bars		43	10	0
Solid Drawn Tubes	lb.	0	1	0½
Brazed Tubes	,,	0	1	0½

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	5	7½
‡Ferro Tungsten ° nominal	,,	0	5	6
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL: 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL: 6–8% Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon. scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	10	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	18	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	2	1	6
Durham	—	1	19	6
Furnace Coke—				
Scotland	—	2	0	0
S. Wales	—	1	17	6
Durham	1 12 6 to	1	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£64	0	0	
*Commercial Ingots	48	0	0	
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars,	£13	10	0
N.E. Coast—			
Rivets	12	15	0
Best Bars	15	15	0
Common Bars	12	10	0
Lancashire—			
Crown Bars	13	10	0
Hoops	14	2	6
Midlands—			
Crown Bars	13	10	0
Marked Bars	15	15	0
Unmarked Bars		—	
Nut and Bolt Bars	11	15	0
Gas Strip	14	2	6
S. Yorks.—			
Best Bars	15	15	0
Hoops	14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	10½
†Sheet to 10 W.G.	,,	0	0	11
†Wire	,,	0	1	0½
†Rods	,,	0	1	0
†Tubes	,,	0	1	6½
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	13	0
Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	13	0
Foundry No. 1	5	11	6
,, No. 3	5	9	0
,, No. 4	5	8	0
Silicon Iron		—	
Forge	5	8	0
Midlands—			
N. Staffs. Forge No. 4	5	8	0
,, Foundry No. 3	5	11	0
Northants—			
Foundry No. 1	5	11	6
Forge No. 4	5	5	6
Foundry No. 3	5	8	6
Derbyshire Forge	5	10	0
,, Foundry No. 1	5	14	0
,, Foundry No. 3	5	11	0
West Coast Hæmatite	7	4	8
East ,, ,,	7	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.195
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.375-405
Per English ton	£19 12 2/£21 4 9
Rolled Martin Iron, basis price.	
Per metric ton	Kr.260-280
Per English ton	£13 12 8/£14 13 8
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton f.o.b. Gothenburg.	£18 17 6

SCRAP METAL.

Copper, Clean	£32	0	0
,, Brazier	29	0	0
,, Wire		—	
Brass	22	10	0
Gun Metal	32	0	0
Zinc	8	0	0
Aluminium Cuttings	71	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	4	2	6
Steel Turnings—			
Cleveland	2	12	6
Midlands	2	5	0
Cast Iron Borings—			
Cleveland		—	
Scotland	2	2	6

SPELTER.

G.O.B. Official		—	
Hard	£10	15	0
English	15	0	0
India	13	0	0
Re-melted	11	0	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,		—	
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester			
Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	0
Finished Bars 18% Tungsten	,,	0	3	10
Extras:				
Round and Squares, ½ in. to ¾ in.	,,	0	0	3
Under ½ in. to ⅛ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅛ in.	,,	0	0	3
,, ,, ½ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash	£168	0	0
English	167	15	0
Australian		—	
Eastern	172	10	0
Tin Plates I.C. 20 × 14 box	1	2	6

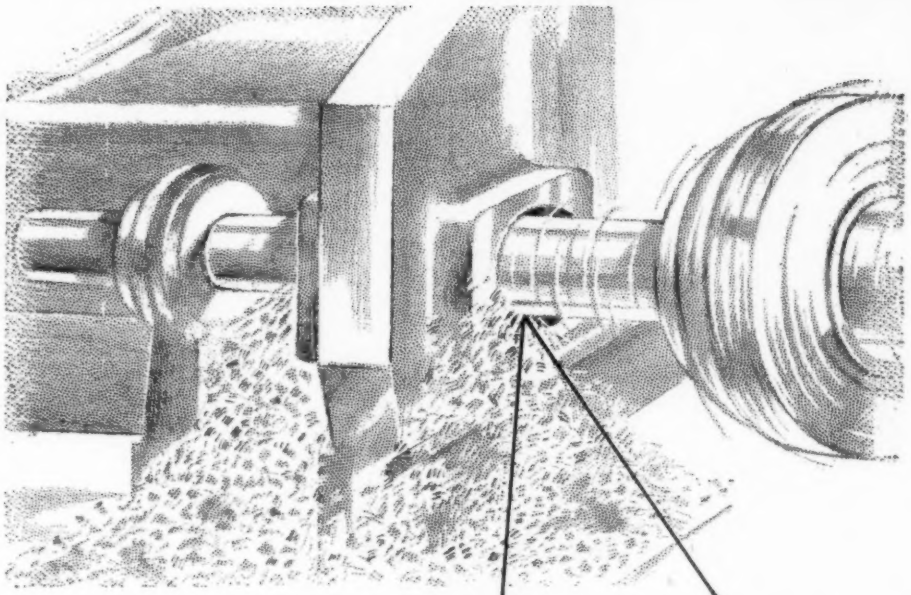
ZINC.

English Sheets	£28	10	0
Rods	20	0	0
Battery Plates		—	
Boiler Plates		—	

LEAD.

Soft Foreign	£15	3	9
English	17	5	0

* McKechnie Brothers, Ltd., Apl. 11. Subject to Market fluctuations.
§ Prices ex warehouse, Apl. 11.
† C. Clifford & Son, Ltd., Apl. 11. Buyers are advised to send inquiries for current prices when about to place order.
‡ Murex Limited, Apl. 11.
¶ The prices fluctuate with the price of Tungsten.



SPEED without limit

"Elektron" magnesium alloys, the lightest available constructional metals, have also the highest machining speeds. Thus to economy in weight must be added the further economy in machining costs. The cutting speeds of these alloys are limited only by the machine power available, not by the quality of the tool steels. The higher the cutting speed the better the results, while all handling is simplified by the ultra light weight of the workpiece (40% less than aluminium).

For all applications demanding lightness allied to strength, "Elektron" British-made magnesium alloys lead. Expert advice on all matters is gladly provided.

Sole Producers and Proprietors of the Trade Mark "Elektron"
MAGNESIUM ELEKTRON LIMITED
Works, near Manchester

•

Licensed Manufacturers
Castings
STERLING METALS LIMITED
Northey Road, Foleshill, Coventry

•

THE BIRMINGHAM ALUMINIUM CASTING (1903) COMPANY LIMITED
Birmid Works, Smethwick, Birmingham

•

J. STONE & COMPANY LIMITED
Deptford, London, S.E.14

•

Sheet, Extrusions, Forgings & Tubes
JAMES BOOTH & CO. (1915) LIMITED
Argyle Street Works, Nechells, Birmingham, 7

•

Sheet, Extrusions, Etc.
BIRMETALS LIMITED
Woodgate, Quinton, Birmingham

•

Suppliers of Magnesium and "Elektron" Metal for the British Empire
F. A. HUGHES & CO. LIMITED
Abbey House, Baker St., London, N.W.1

ELEKTRON

REGISTERED TRADE MARK

MAGNESIUM ALLOYS

The constructional metal with the high strength/weight ratio

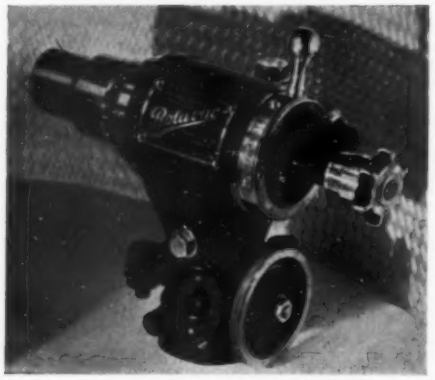
MORE EASILY MACHINED THAN ANY OTHER LIGHT METAL

T.G.S.

"The furnace illustrated is a 1½-ton Heroult unit, operating with Acheson Graphite Electrodes, in the Works of The National Steel Foundry (1914) Ltd., Leven, through whose kindness this illustration is possible."

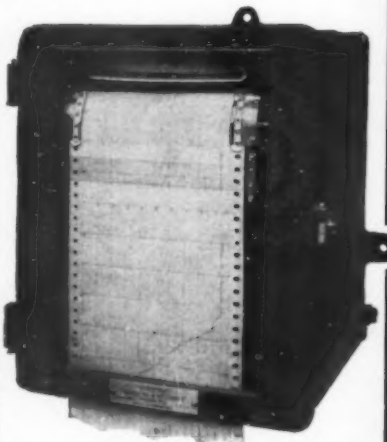
ELECTRODES

BRITISH ACHESON ELECTRODES Ltd.
TOWN HALL CHAMBERS, SHEFFIELD



ROTAVAC
HEAVY OIL BURNER
SAVES 25%
of your
FUEL OIL COSTS
SUITABLE FOR EVERY KIND OF INDUSTRIAL APPLICATION
NU-WAY HEATING PLANTS LTD.
Macdonald Street : Birmingham 5

ETHER PYROMETERS FOR AIRCRAFT PRODUCTION



The instrument here illustrated the **ETHER Recording and Controlling Pyrometer,** is the most accurate and up-to-date Pyrometer to pass the A.I.D. requirements.
Let us quote you for your requirements. For an instrument of such high quality, the price is suprisingly low.
Send for Lists.
Ether Pyrometers for Temperature Measurement
ETHER LIMITED TYBURN RD BIRMINGHAM

THOS. WILKINSON
AND COMPANY LIMITED
Manufacturers ..of.. **FOUNDRY BLACKINGS**
FOR: **INGOT MOULDS, GENERAL HEAVY CASTINGS**
Every Class of Light Castings, etc., etc.
AND
"CARLTON" PATENT BLACKING
FOUNDRY REQUISITES SUPPLIED
EX. STOCK
MOULDERS SINGLE, DOUBLE and TRIPLE STUDS, BELLOWS, BARROWS, SPADES and SHOVELS, SPRIGS, CHAPLETS, CORE GUM, ETC.
Write: **STOCKTON STREET, MIDDLESBROUGH, ENGLAND**
'Phone : **3719 MIDDLESBROUGH**
Wire : **BLACKING, MIDDLESBROUGH**

STERLING METALS LTD

T.G.S.

FILE THIS IN YOUR CABINET

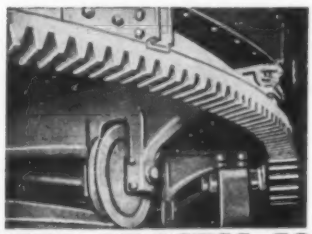
You will then be able to refer to contents of previous issues easily.

METALLURGIA. *Contents.* For APRIL, 1938.

	Page
An Oxygen-Free Copper Development .. .. *A high conductivity copper, substantially free from oxygen, has been evolved, and in this article comparisons are made between this copper and tough-pitch copper.*	207–209
The Thermo-chemistry of Alloys..	210
Rearmament and Industry.. ..	211
Strength Properties of Rolled Mild Steel Sections. By G. Welter and M. S. Wolagiewicz.. *Acceptance tests on structural steel are discussed in connection with the use of structural shapes and the need for greater care in the casting and rolling is shown*	213–217
Strength of Nickel-Chromium Alloys at High Temperatures ..	218
The Protection of Aluminium-Base Alloys Against Outside Atmospheric Exposure. By E. Armstrong .. .. *The advantages of synthetic organic finishing media for the protection of aluminium-base alloys are discussed.*	219–222
Fuels of To-day and Tomorrow ..	222
Controlling Controlled Atmospheres *A fast-growing fund of knowledge on the heat-treatment emphasises the importance of furnace atmosphere, and in this article is described a recent development for measuring and recording furnace atmospheres.*	223–224
The Metallurigcal Inspection of Steel. By J. S. G. Primrose .. *Some outstanding examples, which can be taken as representative and significant, are discussed.*	225–226
Recent Developments in Tantalum and Columbium..	226
High-speed Strip Rolling. By C. E. Davies, M.I.Mech.E. ..	227–228
Lithium—an Alloying Element and De-Oxidising Agent. By Stephen Coleman	228
Reviews of Current Literature ..	229–230
Cartellisation in the World Aluminium Industry. Part III. By Robert J. Anderson, D.Sc. *The disparity between the extensive possibilities of production and the limited possibilities of consumption has presented an economic problem, and the cartel movement is an effort to control producing and marketing activities.*	231–233
United States Aluminium Industry in 1937	233
"K" Monel Metal	234
Deep-Drawing and Pressing Problems. By J. D. Jevons, Ph.D., A.I.C.	235–236
Steels and Their Utilisation for High Steam Pressures and Temperatures. By R. W. Bailey, D.Sc.	237–238

"SHORTER"

Local Surface Hardening with Precision (patented)



All wearing parts can be Shorterised

SHORTER PROCESS CO. Ltd.
Savile Street East, Sheffield 4.

AMSLER TESTING MACHINES

Unequalled for rapid and accurate testing, for ease of operation and for low maintenance costs

T. C. HOWDEN & Co.,
5 & 7, Fleet Street, Birmingham, 3

There is a **"HARDENITE"** case-hardening compound suitable for any case-hardening operation, whether it be a question of uniformity, quick penetration, repetition, absence of freckle, or rapid case-hardening in the open hearth. "Hardenite" compounds are made solely by

The
AMALGAMS Co., Ltd.
184, Attercliffe Rd., SHEFFIELD.

Subscription Form

Please send us **"METALLURGIA"** *monthly until countermanded at our discretion,*
Invoice @ 12/- half-yearly

Name .....

Address .....

.....

21 Albion St., Gaythorn, Manchester 1

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1.

Alloys
J. H. Clifton, London.
Electric Furnace Products Co., Ltd., Norway.

Aluminium and its Alloys
Aluminium Union, Ltd., Bush House, London, W.C.2.
British Aluminium Co., Ltd., King William St., London, E.C.4.
Electric Furnace Products Co., Ltd., Norway.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C.2
Perry Barr Metal Co., Ltd., Birmingham.
Rudge Littley Ltd., West Bromwich.
T. J. Priestman, Ltd., Birmingham.

Anodic Treatment
British Anodising Ltd., Birmingham.

Anti-Friction Metals
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Clifford, Chas and Son, Ltd., Birmingham.
Emery Bros., Ltd., Birmingham.
I.C.I. Metals Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co. Ltd., Handford works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Priestman, T. J., Ltd., Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
Fordath Engineering Co., Ltd., West Bromwich.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., W.C.1.
I.C.I. Cassel Cyanide.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester.

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove Street, Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Road, Middlesbrough.
Woodall Duckham, Vertical Retort & Oven Construction Co., (1920), Ltd.

Crucibles
Morgan Crucible Co. Ltd., Battersea Church Road, London, S.W. 11.

Electrodes
British Acheson Electrodes, Ltd,, Sheffield.

Extruded Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Extruded Rods and Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Forging Machines
Schiess Detries, A.-G., Düsseldorf.

Forgings
Northern Aluminium Co., Ltd., London.

Foundry Preparations.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1,
J. W. Jackman & Co., Ltd., Vulcan Works, Blackfriars Road, Manchester.
Thos. Wilkinson & Co., Ltd., Middlesbrough.

Furnace Arches
Liptak Furnace Arches Ltd., 59, Palace Street, Victoria Street London, S.W. 1.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Electrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., London, W.C. 1.
Integra Co., Ltd., The, 183, Broad Street, Birmingham.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham

Furnaces (Electric)
Morgan Crucible Co. Ltd., Battersea Church Road, London, S.W. 11.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Road, London, N. 7.

Furnaces (Fuel)
British Furnaces Ltd., Chesterfield.
Burdon Furnace Co., 136, West Princes Street, Glasgow.
Cassel Cyanide Co. Ltd., Room 170F2, Imperial Chemical House London S.W.1.
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham.
James Howden & Co. Ltd., 195, Scotland St., Glasgow, Scotland.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
King, Taudevin & Gregson, Ltd., Sheffield.
Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.

Fused Blocks
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1.

Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.

Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester.
Shorter Process Co., Ltd., Savile St. East, Sheffield.

Gun Metal Ingots and Rods
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Hardening Metals
Shorter Process Co. Ltd., Savile St. East, Sheffield.
I.C.I. Cassel Cyanide.

Heating Plants
Nu-way Heating Plants, Macdonald Street, Birmingham.

Ingots (Non-Ferrous)
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Machine Tools
Sanderson Brothers and Newbould Ltd., Sheffield.

Magnesium Alloys
F. A. Hughes, Ltd., London.
Magnesium Castings, Ltd., Slough.
Sterling Metals, Ltd., Coventry.

Magnetic Separators, Clutches, Chucks, and Lifting Magnets.
Electromagnets, Ltd., 48, High Street, Erdington, Birmingham.

Metal Spraying
Cromalin, Ltd., Birmingham.

Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.

Non-Ferrous Metals
Birmetals, Ltd.
Reynolds Tube Co., Tyseley, Birmingham.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Perry Barr Metal Co., Ltd., Birmingham.

Pig Iron
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furnace.
Bradley & Foster, Ltd., Darlaston.

Presses
Eumuco Ltd., Beverley Works, Willow Ave, Barnes, London, S.W. 13.
Schloemann, A.-G., Dusseldorf, Germany.

Protection of Metal Parts for Use at High Temperatures.
Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.

Pulverised Fuel Equipment
Alfred Herbert Ltd., Coventry.

Pyrometers
Cambridge Instrument Co., Ltd., London.
Electroflo Meters Ltd., Abbey Road, Park Royal, London, N.W. 1.
Ether, Ltd., Tyburn Road, Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas Street, London.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.

Recording Instruments
Cambridge Instrument Co., Ltd., London.
Dine Engineering Co. 60, Mount Street, Nechells, Birmingham.
Electroflo-Meters Co., Ltd., Abbey Road, Park Royal, London, N.W. 10.
Ether, Ltd., Tyburn Road. Birmingham.
George Kent Ltd., Luton, Beds.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham

Refractories
Carborundum Co., Ltd., Trafford Park, Manchester.
J. and J. Dyson, Ltd., Stannington, Sheffield.
Kingscliffe Insulating Products, Ltd., Sheffield.
Thos. Marshall and Co., Loxley, near Sheffield
Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W, 11.
John G. Stein & Co., Bonnybridge, Scotland.

"Sea Cliff" Brand

COPPER, BRASS and PHOSPHOR BRONZE

TUBES, SHEETS, RODS and WIRE

"Aldurbra" Aluminium-Brass Condenser Tubes,
Protected under B.N.F Patent No. 308647—1929.

Manganese Bronze. Yellow Metal. Naval Brass. Gun Metal.
High Conductivity Copper Bars and Strip.
Tin, Lead, Zinc and Compo Wire and Strip.
Chill-Cast Phosphor Bronze Bars.
Engraving Bronzes, Gilding Metals, and Engraving Brasses.
Phosphor Copper and Phosphor Tin.
Non-Ferrous Wires for Metal Spraying.

Trade Mark.

CHARLES CLIFFORD & SON LTD.
Telegrams: Clifford Birmingham.
Telephone: Mid. 2152, Pte.-Bch.Ex. BIRMINGHAM
ESTABLISHED 1776.

Contractors to Admiralty, War Office, Air Board, Railway Companies, etc.

Roll Grinding Machines
Craven Bros. Ltd., Reddish. Stockport.

Roll Manufacturers
Tennent Ltd., Whifflet Foundry, Coatbridge, Scotland.

Rolling Mills
Demag, A. G., Germany.
Ehrhardt and Sehmer, Saarbrücken.
Fried. Krupp Grusonwerk A.-G. Magdeburg, Germany. Sole Agents in Great Britain: J. Rolland and Co., 2 Victoria Street, London, S.W. 1.
Lamberton and Co., Coatbridge.
Maschinenfabric Froriep, Rheydt, Germany.
Rheinische Walzmachinenfabrik, Germany.
Robertson, W. H. A., and Co., Ltd., Bedford.
August Schmitz, A.G., Germany.
Karl., Fr. Ungerer., Germany.

Silver Solder
Chas. Harrold & Co. Ltd., 283, St. Paul's Square, Birmingham.

Steels
Barrow Hæmatite, Steel Co., Ltd., Barrow-in-Furnace.
Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield.
Daniel Doncaster & Sons, Ltd., Sheffield.
Dunford & Elliott, Ltd., Sheffield.
Thos. Firth & John Brown, Ltd., Sheffield.
English Steel Corporation Ltd., Sheffield.
Sanderson Bros. and Newbould, Ltd., Sheffield.
United Steel Companies, Ltd., Sheffield.

Steel Sections
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furnace.

Steel Tubes and Sections
Reynolds Tube Co., Tyseley, Birmingham.

Steelworks Plant
Wellman Smith Owen Engineering Corporation, Ltd., Victoria Station House, London, S.W. 1.

Temperature Controllers
Cambridge Instrument Co., Ltd., London.
Electroflo-Meters Co. Ltd., Abbey Road, Park Royal, London.
Ether, Ltd., Tyburn Road, Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas Street, London S.E 1.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
George Kent, Ltd., Luton.

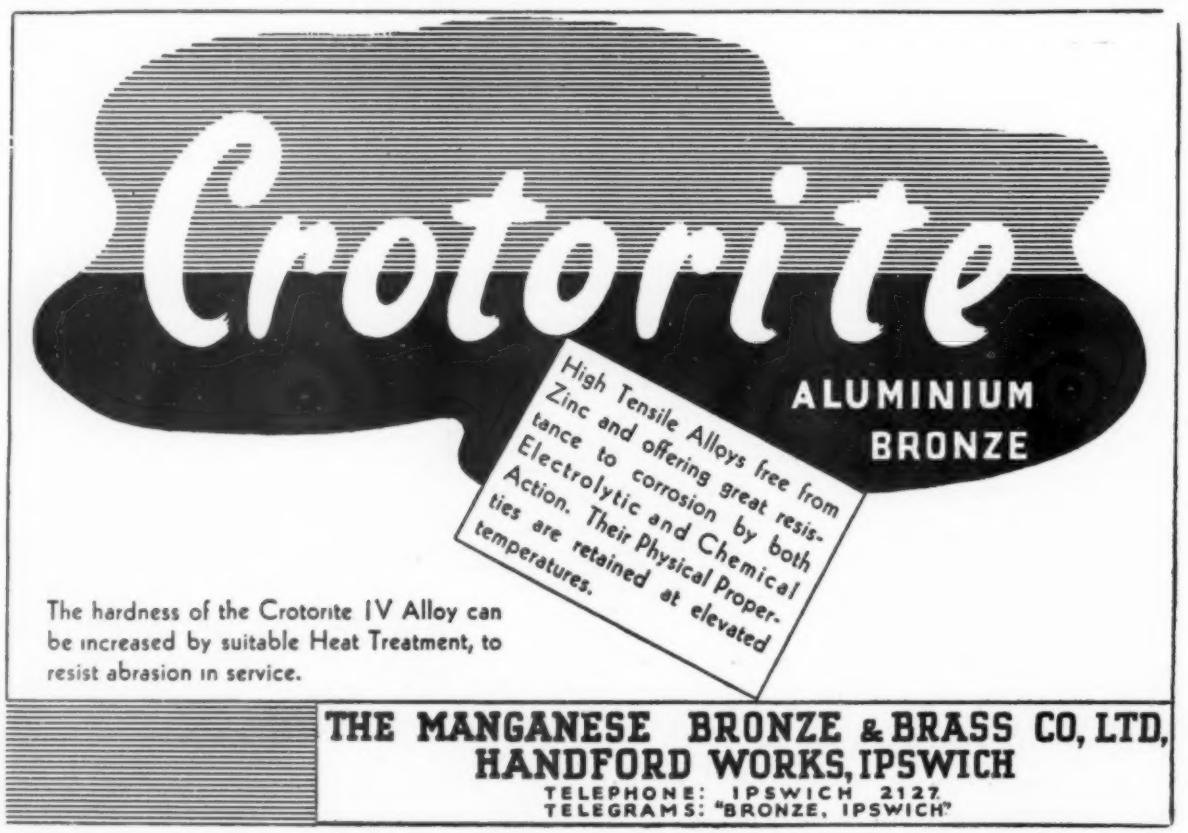
Testing Machines
Howden, T. C., and Co., 517, Fleet Street, Birmingham.

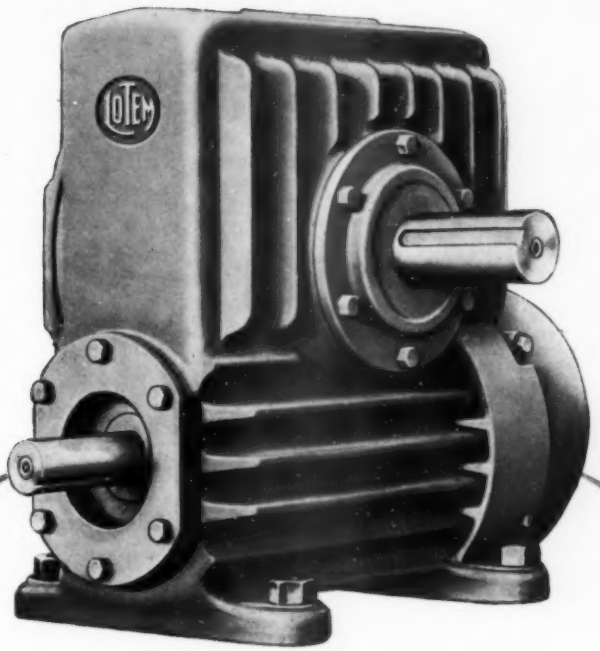
Tube Drawing Plant
Sundwiger Eisenhütte, Sundwig, Germany.

Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

Index to Advertisers.

	PAGE
Edgar Allen, Ltd.	—
Aluminium Union, Ltd.	36
Amalgams Company, Ltd.	42
Associated British Machine Tool Makers, Ltd.	34
Barrow Hæmatite Steel Co., Ltd.	18
Birmetals, Ltd.	19
Birmingham Electric Furnaces, Ltd.	20
British Acheson Electrodes, Ltd.	40
British Aluminium Co., Ltd.	15
British Commercial Gas	27
British Furnaces	—
Carborundum Co., Ltd.	3
Clifford, Chas., and Son, Ltd.	43
Demag, A.G.	23
Demag Elektrostahl	30
Doncaster, Daniel, Ltd.	—
Dowson & Mason, Ltd.	34
Electric Furnace Co., Ltd.	—
Electromagnets Ltd.	—
Electroflo Meters Co., Ltd.	21
Electric Furnace Products Co., Ltd., Norway	31
English Steel Corporation, Ltd.	—
Ether, Ltd.	40
General Electric Co., Ltd.	—
Gibbon Bros., Ltd.	10, 11 and 25
G.W.B. Electric Furnace Co.	—
Harrold, Charles & Co., Ltd.	4
Herbert, A., Ltd.	—
High Duty Alloys, Ltd.	5 and 6
John Holroyd & Co., Ltd.	—
Howden, T. C., and Co.	42
Hughes, F. A. Ltd., London	39
Imperial Chemical Industries, Ltd.	22 and 32
Incandescent Heat Co., Ltd.	32
Industrial Art Services, Ltd.	30
Integra Co., Ltd.	7
Kasenit Ltd.	—
Kent, George, Ltd.	Front Cover
King, Taudevin & Gregson, Ltd.	24
Krupp Grusonwerk A.-G.	28
Magnesium Castings & Products Ltd.	—
Manganese, Brass & Bronze Co.	44
Marshall and Co.	33
Maschinenfabrik Froriep	—
McKechnie Brothers, Ltd.	Inside Front Cover
Metalectric Furnaces, Ltd.	—
Metro-Vickers, Ltd.	12
Mills, Wm., Ltd.	8
Mond Nickel Co., Ltd.	9
Morgan Crucible Co.	—
Northern Aluminum Co., Ltd.	17
Nu-way Heating Plants	40
Ofag Ofenbau	4
Priest Furnaces, Ltd.	14
Reynolds Tube Co. Ltd.	Outside Back Cover
Rheinische Walzmaschinen	—
Robertson, W. H. A., and Co., Ltd.	26
Sanderson Bros., and Newbould, Ltd.	38
Schmitz A.G.	8
Schloemann, A.-G.	16
Shorter Process Co., Ltd.	42
Stein, J. G., & Co., Bonnybridge, Scotland	38
Sterling Metals, Ltd.	41
Siemens Schuckert.	29
Sundwiger Eisenhütte	13
Thermal Syndicate, Ltd.	Inside Front Cover
Ungerer, Karl Fr.	35
United Steel Companies, Ltd.	—
Wallwork, Henry, and Co., Ltd.	Inside Back Cover
Wellman Smith Owen Eng. Corp. Ltd,	—
Wild-Barfield Electric Furnaces, Ltd.	—
Wilkinson, Thos.	40


Crotorite
ALUMINIUM BRONZE
High Tensile Alloys free from Zinc and offering great resistance to corrosion by both Electrolytic and Chemical Action. Their Physical Properties are retained at elevated temperatures.
The hardness of the Crotorite IV Alloy can be increased by suitable Heat Treatment, to resist abrasion in service.
THE MANGANESE BRONZE & BRASS CO, LTD,
HANDFORD WORKS, IPSWICH
TELEPHONE: IPSWICH 2127
TELEGRAMS: "BRONZE, IPSWICH"



MAKE SURE IT'S THE

BEST WORM GEAR

ALWAYS SPECIFY

WALLWORK

HENRY WALLWORK & CO. LTD. MANCHESTER

LOTEM

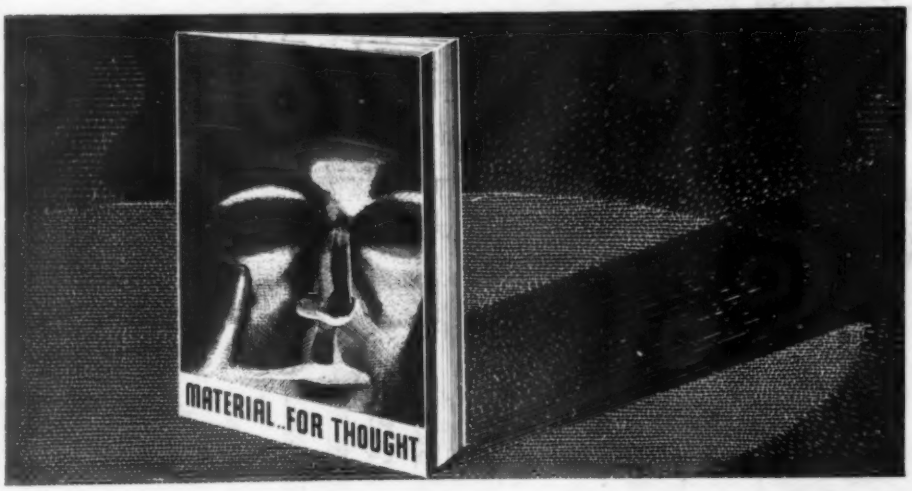
FAN COOLED

Printed for the Proprietors, The Kennedy Press, Limited, 21, Albion Street, Gaythorn, Manchester, by Percy Brothers (1937), Limited Hotspur Press, Manchester and London.

PROGRESS IN THE MAKING

This is the story of how we started our cycle of life practically contemporary with the steel-tubed cycle . . . how, in an age when "children should be seen and not heard," we "butted in" rather precociously (We were then known as the Patent Butted Tube Co.) Now we're 42 years old, and the expansiveness of our works reveals "that middle-age spread." Right back from 1896, we've been making steel tubes of EXTRAordinary shapes and sizes, and developing NEW types of steels that set new standards for all kinds of transport. We found ourselves famous on land, sea and in the air—apparently our fame continues to grow—rapidly. Came the Age of Alloys, when certain sections of opinion saw how sections in Aluminium Alloys could, with advantage, replace heavier metals. So, having wrought miracles in steel, we started working miracles in Aluminium Alloy components to lighten the lot of Industrial progress. That was four years ago. To-day . . ! We have prepared a very interesting book that puts a new construction upon to day's constructiveness, and written for constructive thinkers who build for the present AND the future.

THIS BOOK WILL INTEREST YOU MAY WE SEND YOU A COPY ?



REYNOLDS

TUBES, RODS, EXTRUDED SECTIONS, SHEET & STRIP IN HIGH STRENGTH ALUMINIUM & MAGNESIUM ALLOYS

REYNOLDS TUBE COMPANY LIMITED REYNOLDS ROLLING MILLS LIMITED

TYSELEY, BIRMINGHAM, 11